THE USE AND MANAGEMENT OF WOODLANDS FOR THE OUT-WINTERING OF FARM STOCK

by

N.G. BORISSOW, B.Sc.

M.Sc., 1962.

PREFACE

This thesis is presented for the degree of M.Sc. in the University of Edinburgh and has been prepared in accordance with the regulations for this degree. The work is a report of research carried out in the Department of Forestry of the University of Edinburgh between September 1960 and December 1962 into the use of woodland and forest for out-wintering farm stock and the problems associated with this practice.

The study is in three parts. Part 1 consists of a review of literature concerning the use of forested land for grazing in several countries of the world and the effects of such use on livestock, the forest and forest management. Part 2 deals with the applicability of previous research to Scottish conditions and possible further developments, together with a discussion on the information obtained from field studies, while Part 3 contains detailed descriptions of six selected sites and suggestions for the management of these areas for out-wintering farm stock.

Acknowledgement is due to all those who have contributed towards this work: the Department of Agriculture and Fisheries for Scotland and the Department of Forestry of the University of Edinburgh for initiating and bearing the expenses of this research project; the County Agricultural Advisers for locating areas of woodland grazing; the many landowners, factors, foresters, farmers and shepherds who have shown the author round their particular areas and

and discussed the problems of out-wintering in woodlands so willingly and patiently; The British Aluminium Company Limited for permission to work on their estates and especially Mr.A.N.S.Kinnear, Forestry Officer, for the arrangement of field study facilities, advice and enthusiastic encouragement, and all other employees who supplied information; The Right Honourable Lord Glentanar, K.B.E., for field study facilities in Glen Tanar, and both Mr.R.D. Young, Factor, and Mr.D.Ross, Head Forester, for advice; the Forestry Commission for field study facilities in Tentsmuir Forest, and the local staff of this forest for advice; Dr.A.M.Smith of the Chemistry Department, Edinburgh School of Agriculture, for chemical analyses of soil and herbage samples; Dr.D.Purves, Spectrographic Department, Edinburgh School of Agriculture, for spectrochemical analysis of herbage and leaf litter; Dr.J.B.D.Herriott, Botany Department, Edinburgh School of Agriculture, for help and advice on the identification and use of grasses; other members of the staff of the Edinburgh School of Agriculture for help and advice; the late Professor M.L.Anderson, M.C., M.A., D.Sc., F.R.S.E., Professor of Forestry in the University of Edinburgh, for advice and encouragement during the first year of this work; Dr.J.M.Caborn, Department of Forestry, University of Edinburgh, for advice, encouragement and guidance throughout; Mr.J.E.Cousens, Department of Forestry, University of Edinburgh, for botanical identifications; to the members of the staff of the Department of Forestry, University of Edinburgh, for advice and suggestions on many aspects of the work; Mrs.A.C.H.Watson for her valuable work in typing the thesis and, finally, to my wife, for very considerable help in surveying and collection of mensurational data.

13/12/62.

CONTENTS

Page

INTRODUCTION

Just over 11 million acres, or 57% of the total land area of Scotland, is classified as rough grazings (Agric. Statistics, Scotland, 1958), and most of this is in hill and upland farms where sheep are the dominant livestock on the former with varying proportions of cattle and sheep on the latter. Both, however, are concerned with the production of store livestock and will be referred to in future as "hill" farms. These hill farms have certain characteristics in common. They are:

(i) Sheep and hardy cattle remain on the hill throughout the year,

(ii) A seasonal production of herbage; an abundance in summer and a dearth in winter,

(iii) A rigorous winter climate and,

(iv) Annual pregnancies of livestock coincide with the period of minimum natural food supply.

It is hardly surprising, therefore, that where hill farming is practised, and this applies to all counties in Scotland except West Lothian (Wannop, 1958), the shelter provided by trees and shrubs should be used extensively to ameliorate the winter environment of farm stock.

It is still the practice in Scotland to allow cattle and sheep to graze through coppice, scrub and other relatively unproductive woodland at all times of the year, for the benefits of shelter from trees, especially during the winter months, have been known for a long time. In 1949, when the Forestry Commission carried out its last Census of

Woodlands, there were 256,683 acres of scrub woodland in Scotland described as "... of inferior growth unlikely to develop into a utilizable crop of coppice, poles or timber." This is 20% of the total wooded area of Scotland. It is probably in woodland such as this that most of the grazing has been taking place. But since the last war these areas have been looked upon as a reserve of land for many uses. Accordingly, some has been reclaimed for agriculture and some rehabilitated into productive forest land. While few would disagree with such action, it is on the remaining area of unimprovable forest land that attention has been focussed in recent years. It is believed that scrub woodland, and indeed tree cover in general, is of value for out-wintering farm stock in Scotland. However, these areas are said to be disappearing gradually, for the aphorism "forestry and grazing are incompatible" is, with reservations, generally true.

Thus in September, 1960, the Department of Agriculture and Fisheries for Scotland, in conjunction with the Department of Forestry of the University of Edinburgh, initiated this research project to investigate the practice of out-wintering farm stock on forested land. Early on in the work it was found that not only scrub and unproductive woodland was being used for this purpose but also valuable and highly productive woodlands and forests. Therefore it was considered necessary to extend this study to include all types of woodland and not just scrub woodland, as was the original intention, and it was decided that the objects of the work should be:

(1) To establish the actual and/or potential value of woodlands for out-wintering farm stock in Scotland,

(2) To find some method of regenerating these woodlands and,

(3) To look into the problems involved in the management of such woodlands.

PART I

REVIEW OF PREVIOUS LITERATURE

CHAPTER 1

HISTORICAL

(In this chapter, any reference to Anderson, without a date, refers to the typescript of his work "History of Scottish Forestry" - unpublished.)

1. Mesolithic and Neolithic Ages

Our forests can be regarded as starting from the end of the last Ice Age, that is approximately 12,000 B.C. (Anderson). But it is uncertain when man first made his appearance in this country. The Encyclopaedia Brittanica (1959) mentions that mesolithic remains have been found in Scotland and Steven and Carlisle (1959) state that man reached Scotland, probably from north-east Ireland, about 5,000 B.C. Yet Mackinnon (1892) implies that man was here in Early Stone Age times. However, there seems little doubt that these early inhabitants had no great effect on the natural vegetation, even though the axe was first invented and used during the mesolithic period (Encyc. Britt. 1959). These people were food gatherers (Tansley, 1949) and lived mostly by trapping (Edlin, 1956), hunting (Trow-Smith, 1957) and fishing (Anderson).

Of great importance was the arrival of Neolithic man in Britain in about 2,500 B.C., as he brought with him cereals, domesticated animals and the art of fire-making (Encyc. Britt. 1959). The conditions prevailing at this time have been described by many authorities. Anderson states that all but the shallowest soils would have been covered in forest, which was predominantly of the moist oakwood type, containing, apart from oak, elm, hazel, birch and juniper, to which Tansley (1949) would add lime. The oak forest was on the lower ground and on the heavier soils, where alder may also have been a minor constituent. At higher elevations this would give way to a dense, scrubby type of woodland with scattered large trees of oak, ash and elm (Anderson). Pine occupied the drier hill tops and also the shallow soils overlying the sands and gravels, while a pine/birch mixture was present leading up towards the tree limit which gave way to pure birch, in eastern districts pure pine, to the tree limit.

The natural fauna roaming the forests at this time was impressive. Piggott (1954) gives pride of place to the wild ox (Bos primigenius) which was an animal of the woodlands. He also mentions the presence of red deer (Cervus elaphus), roe deer (Capreolus capreolus), wild horses (Equus spp.), wild boar (Sus scrofa), beaver (Castor fiber) and brown bear (Ursus arctos). In addition, Ritchie (1920) notes the following inhabitants: reindeer (Rangifer tarandus), elk (Alces alces), wolf (Canis lupus) and European lynx (Lynx lynx). It is important to note the presence of the predatory animals in these lists for just as, at this time, they were indirectly responsible for the survival of the forests by keeping the numbers of herbiverous animals in check so, later on in history, they were indirectly responsible for the accelerated deforestation of Scotland, as will be explained in a later chapter.

From this environment Neolithic man had to carve out room for his existence. He was primarily an agriculturist, with stock raising being of prime importance and corn growing a subsidiary enterprise (Stamp, 1955). For these activities he needed land fairly free of forest cover; room for his primitive fields round his settlements and pastures for the grazing animals. To satisfy these requirements Stamp (1955) says that they settled first on open ground or where the woodland was sparse and could be cleared easily, while Anderson states that the invasion of the forest was probably from the coast and points along rivers where the trees were less dense, due to the sandy and gravelly nature of the soil. This seems very likely as neolithic man was ill-equipped for large scale forest clearance. Indeed Piggott (1954) is of the opinion that fire played a more important part than tree-felling in forest clearance at this time. Nevertheless, Anderson thinks that the inroads into the forests during this period were small and Steven and Carlisle (1959) are in agreement with him.

The domestic animals of neolithic man were sheep, cattle, goats, pigs and horses. According to Trow-Smith (1957) the sheep was introduced in its domesticated form, for no possible wild prototype existed here. The same authority ascribes the introduction of the Celtic Shorthorn to neolithic man. Steven and Carlisle (1959) record the introduction of goats at this time but the pig and the horse (Ritchie, 1920) seem to have been tamed and domesticated from the wild stock of the forests.

The habits of these animals were not far removed from those of to-day. The sheep is an animal of the open pasture or low scrub (Trow-Smith, 1957) and Franklin (1953) records that the neolithic shepherd knew the grass of the marshy oak forests in the valleys was dangerous to sheep owing to infestation by liver fluke. Accordingly, sheep pastures were confined to the open hill tops. The Celtic Shorthorn, however, was an animal of the forest and was able to win much of its food from the leaves of the trees (Trow-Smith, 1957). It also foraged in the oak forests with pigs (Franklin, 1953). The horse, too, according to Trow-Smith (1957), was a forest animal in its wild and half-wild state.

Thus it can be seen that the forest was expected to provide food for a great variety of creatures, including man. But what of the winter time? Practically the whole of the forest cover was deciduous. Consequently an important source of food, in the form of foliage, would be lacking. A hay harvest, according to Trow-Smith (1957), must have been impossible before the appearance, in the Iron Age, of the sickle.

Neolithic man used every resource at his disposal to keep himself and his stock alive through the winter months. Both Franklin (1953) and Symon (1959) say that many animals were slaughtered in the autumn to ease the problem of winter feeding. The cattle that escaped these autumn slaughterings were probably wintered in clearings in the forest where they found food and shelter (Franklin, 1953.) Churchill (1957) records the use of hilltop earthwork enclosures into which cattle were driven at night time and doubtless it is to some similar primitive construction that Symon (1959) refers when he says that houses were provided for cattle in winter. Trow-Smith (1957) states that in the absence of hay, the herds at this time must have existed on the grasses left uneaten in the summer grazing season and also, perhaps, upon conserved foliage, bark and seaweed. Seaweed, he mentions, was, and still is, one of the major winter fodders in the remote coastal regions of Scotland.

The Neolithic Age was short, lasting from about 2,500 B.C. to 2,000 B.C. (Tansley, 1949, and Edlin, 1956) and it has been agreed by several authorities that little forest clearance took place during this period. It has also been shown that at this time forests were being used for wintering stock, and in addition, minor forest produce was of considerable importance during the winter.

2. Bronze Age

Following closely upon the Neolithic settlers came the "Beaker" peoples, to initiate the Bronze Age in 2,000 B.C. (Trow-Smith, 1957). Like neolithic man he was, according to Anderson, a stock-rearer and farmer though no doubt, as Churchill (1957) says, they also lived by hunting and fishing.

Anderson records that they settled mainly in the sandy areas and Churchill (1957) says that for the most part Bronze Age man colonized the gravel on river banks or the light upland soils.

During this period Darling (1955) states that the north-west of Scotland was probably close forest to over

2,000 feet, inhabited by wolves, bears, wild ox, moose and lynx, while in Central Scotland Stamp (1955) says that the forest extended to 3,000 feet.

According to Anderson the population was increasing and the communities were becoming more or less fixed. With better cutting tools the forest was laid waste more quickly to make way for agriculture, grazing and man's timber needs. It was in the birch and aspen forests lying above the mixed oak forests, where the first extensive cuttings must have been made (Anderson), especially on the fertile soils where grass would quickly colonise the clearings. Franklin (1953) enhances this view by saying that about 2,000 B.C. the reappearance of grass and ribwort plantain signified the first cutting of the forests by Bronze Age man. Anderson points out that a considerable depression of the tree-line must have resulted because grazing and exposure would have prevented recolonisation by trees on the cleared areas. Consequently, as the woodland receded under climatic change and human expansion there was a rise in the sheep population and a corresponding decrease in that of the ox and pig (Franklin, 1953).

It is in the Bronze Age, therefore, that we see the first significant cutting of the forests.

3. <u>Iron Age</u>

The Encyclopaedia Brittanica (1959) states that the Iron Age started around 800-750 B.C. As the Bronze Age lasted till 500 B.C. (Stamp, 1955), there was a considerable overlap of cultures until finally the superior iron weapons overcame Bronze Age man.

These Celtic invaders knew the use of iron and with their superior tools and weapons many changes took place. They inhabited the high ground and lived in hill forts (Churchill, 1957) for which large amounts of timber were needed (Anderson). This was obtained from the high-lying areas where the trees were smallest (probably birch) and therefore easier to clear, says Anderson, and after clearance, the rich soil was turned over to agriculture and grazing, thereby guaranteeing the prevention of regeneration of these areas.

Up to 750 B.C. the problem of over-wintering stock was still unsolved. But the iron-using settlers brought with them the slasher and scythe. This was a most important development, as, with a scythe at man's disposal, a hay harvest was now possible, and according to Franklin (1953) and Trow-Smith (1957) haymaking dates from the introduction of this tool in about 750 B.C. The slasher, too, was a most valuable implement as this made the collection of fodder very much easier and as a result probably a great deal of foliage was collected in the late summer and conserved for winter use to eke out the hay ration.

About 500 B.C. Manley (1952) says that a cooler, damper climate (Sub-Atlantic) set in which lowered the tree-line by perhaps 1,000 feet. Franklin (1953) states that because of this cattle could no longer be kept in the open during the winter. This implies two things. First, that before this date it was possible to out-winter stock satisfactorily, and second, that after this date some form of shelter, presumably a building of sorts, was employed for the winter months. The first implication may have some significance for according to Manley (1952) and Lamb (1959) the climate now shows a tendency towards increasing dryness and warmth. If this is so it should become, theoretically, more easy to out-winter stock than during most of the last two millennia.

The shieling system dates back to Iron Age times according to Franklin (1953), and Edlin (1956) mentions that the main grazing grounds lay in the "outfield" or open pastures of the forest, which were never enclosed or tilled, control of livestock being by herding or by fencing with stone walls or wattles.

Up to this time there is no evidence to suggest that any type of management of the forest was carried out, even in a primitive form. Consequently, Anderson says that by the time of the Roman invasion the lighter birch forests had been severely thinned out or completely cleared and a start was being made on the moist oakwood forests.

4. <u>50 B.C. to 15th century</u>

It seems doubtful whether the Belgic and Roman invasions had much effect as far north as Scotland, and Edlin (1956) mentions that even the Anglo-Saxons and Normans never penetrated the northern and western Highland Zone, although according to Churchill (1957) the Lowlands were subjugated by the Normans and a loose feudal system of land tenure prevailed.

<u>11th century.</u> In the 11th century Anderson states

that stock was beginning to be of more value to people. This may have been due to the fact that predators and other fierce animals had decreased in number, for according to Trow-Smith (1957) the brown bear had disappeared in the 9th century and Ritchie (1920) records that the elk also died out in the 9th century, the Great Urus in the 9th to 10th century with the reindeer following soon after in the 10th to 12th century. The wolf, however, was still a serious menace to both man and beast. Nevertheless, grazing assumed greater importance at this time. Pasture and woodland were common land and every villager had the right to graze a certain number of animals within the forest. These forests skirted the arable land and besides sheltering the crops, provided pasturage for numerous herds of cattle, horses, sheep and pigs.

12th century. It was the Monks, in the 12th century, who greatly encouraged sheep farming (Franklin, 1953). The source of this industry was in the Cheviots and Southern Uplands and Anderson has described the condition of the northern slopes of the Cheviots at this time. The middle and lower slopes were covered with a short, open leaf-tree forest, with occasional larger trees, under which was grass, making excellent pasture for sheep. The Monks were able to keep considerable flocks of sheep in this type of woodland and by the end of the century it had become so valuable that a right had to be obtained to leave stock at large in such places. In addition, the use of forests for pannage was well known by this time and was considered a valuable privilege as can be seen by the many old charters which granted Monks a right to keep stock in the woods.

As for management of woodlands at this time, there was little or none of a positive kind. Ritchie (1920) says, "the danger which threatended the woodland from the promiscuous pasturing of flocks was recognised by the old Scottish laws, attributed by some to the time of William the Lion in the later years of the 12th and early years of the 13th centuries, under which trespassing sheep were impounded and in some cases killed." But no provision was made for the simultaneous use and regeneration of the forests.

13th century. Thus, by the 13th century the Forest of Ettrick was described by King Alexander II as "my whole waste of Ettrick" (Franklin, 1952.) However, in more fortunate regions the forests were still being used for stock-rearing. Franklin (1953) records that on the hill-sides and valleys bordering the estate of Coupar Abbey, there were forest grazings and pastures where the tenants were bound to keep the abbey's stock on their own holdings. Indeed, it was a condition of tenure that they pastured 40-100 cattle each in summer, or wintered 10 cattle each. The cattle referred to were the hardy black cattle of the period and it was only in the sheltered glens and forests of the lower ground that this out-wintering was tried, with success it seems, for Franklin (1953) records that the leases were renewed on the same terms over a period of sixty years.

Cattle and sheep were not the only animals to use the forest extensively. Anderson says that horses were a common feature of grazing during the 13th century, for it was a custom that they were allowed to graze and browse freely so long as they were being used for work in the forest.

14th century. Throughout the 14th century sheep farming continued to spread in the Southern Uplands as the wool trade grew in importance, and more and more land was turned over to sheep farming. Both Manley (1952) and Lamb (1959) record a deterioration in climate around this century but it appears to have had little effect as far as stock-rearing is concerned.

15th century. A dearth of timber was already being felt in Scotland by the 15th century (Tansley, 1949). Perhaps due to this, one can see the beginnings of organised use of the forest and forest products. However, again the initiative rested with the Monks. Franklin (1952) mentions that an Act of Parliament in 1437 required all the King's tenants to plant trees and protect them against animals. This was done conscientiously by the monks of Coupar Abbey. A wall was built round their forest of Campsie and further walls divided it into four parts, the object being to prevent cattle from straying all over the forest while one part was being felled. The clearings in the forest were grazed and cultivated. Franklin (1952) estimates the area of these clearings to be at least 45 acres. Therefore it seems that by this time the state of the countryside in the Southern Uplands and Central Lowlands was one of fields surrounded by woodland in the form of shelterbelts, rather than forest in which there were fields.

It can be seen by now that the part played by forests in stock-rearing has been completely reversed. In B.C. times forests were dominant and stock obtained a considerable amount of their food from them, both directly in the form of foliage and fruits of the trees, and indirectly, from herbage present on the forest floor. These forests were probably considered as inexhaustable and hence used quite freely and wastefully. The advantage of shelter would then, quite naturally, go unrecognised. In early mediaeval times when there was probably a better balance between forest, pasture and arable land, the forest was greatly valued for stock-rearing, due presumably to the variety of food to be obtained within it together with the advantages of shelter and major and minor forest produce. However, there was still comparatively plenty of woodland in existence and therefore not much attention was paid to its management. But by the end of the 15th century forests no longer seemed to contribute to the welfare of stock as in the past, but were conserved more for timber production. One possible explanation comes to mind. It is very difficult to appreciate a thing unless one has been without it, and when applied to the indirect benefits of forestry this statement has some relevance, for it has been shown that before this period there had been adequate forest cover in which to graze and shelter livestock and the value of woodland for these purposes may have gone unnoticed simply because no-one had experienced conditions without it. But with a shortage of timber in the 15th century, the remaining woodland was protected with the result that stock were deprived of a natural source of food and shelter and only when man had to provide the balance artificially did he fully recognise the advantages of a woodland environment.

However, there may have been little need for shelter at this time, in which case the beneficial effect of tree cover towards amelioration of local climate would not have been obvious, but from mid-16th century to the present day there is evidence that man has regretted the rather haphazard way in which the forests have been used.

5. <u>16th to 20th century</u>

As was mentioned in the last section, the value of shelter may only have been fully realised because there was so little of it. But what appears to be of equal importance is the fact that Lamb (1959) mentions that after about 1500 winters became harsher and upland villages were abandoned perhaps partly for this reason. Thus the period 1550 to 1850 has been referred to as the Little Ice Age. Lamb continues with his description by saying that east winds were prominent in the early stages (1550 to 1600) and poor summers and harsh winters brought years of dearth in Scotland, especially in the 1590s, 1690s and 1780s. It was mentioned, too, that the woods were dying near the north-west coast of Scotland, perhaps owing to increased windiness and salt spray, and these shores still remain treeless today.

It is probably true to say that the beneficial effects of the remaining tree-cover would seem greater and be more impressive at this time than during previous centuries owing to the deterioration in climate, for the greater the extremes in weather conditions the more efficient, relatively, will a piece of woodland seem to be in ameliorating those conditions. It is therefore obvious why the terms "shelter" and "wintering of stock" are mentioned more frequently from now on in historial writings.

16th century. So, at the beginning of the 16th century Franklin (1953) still records that cattle were being killed to ease the problem of winter feeding and Symon (1959) mentions that broom parks were established to provide fodder for stock in winter and tree loppings were used to augment the winter food supply.

Anderson states that in 1503 James IV had 20,000 sheep in Ettrick Forest and that the Crown used certain forests for the purpose of breeding horses. Franklin (1953) notes that by 1530 King James V had only 10,000 sheep in Ettrick Forest in competition with the flocks of the Border abbeys. Thus in a matter of 27 years the number of sheep in this forest had decreased by 10,000, surely a sign that the area had been vastly over-stocked.

17th century. Towards the end of the 17th century Symon (1959) says that a run of extremely bad seasons caused famine and death, the effect being felt from 1693 to 1702. This is in agreement with Lamb's records of deterioration of weather mentioned earlier in this section. In 1694 the Recorder for Muckairn Parish, Argyllshire, is quoted by Anderson - "The woods, whereof it hath as yet great plenty, are oak, birch and alder, are much impaired, especially the oak, which is generally old stocks, so knotty and cross-grained, that it is of little use but to shelter cattle in bad weather, and to entertain some scores of roes that frequent them."

Also during this century there was a determined effort in Scotland to exterminate the wolf. Up till now large scale sheep farming had been impossible in the Highlands owing to the large numbers of wolves (Franklin, 1953). These creatures had been hunted intermittently for a very long time but this method of control was not very effective. As direct methods had failed, indirect ones were used, this being the elimination of the wolf's habitat. Thus large areas of forest in the Highlands were burnt (Ritchie, 1920) to rid the countryside of this troublesome predator, which was preventing the spread of sheep farming to the Highland Zone. This method was successful, as according to Ritchie (1920) the last wolf in the north-eastern counties was slain in Kirkmichael Parish, Banffshire, in 1644; the last in Perthshire at Killiecrankie in 1680 and the last in Forfarshire also in that year. So it could be said that the wolf was indirectly responsible for some of the accelerated deforestation of the Highlands.

Steven and Carlisle (1959) state that the Highland woods, partly owing to their inaccessibility, do not appear to have been exploited to any extent for use outwith the region until 1600. But unfortunately, during the latter half of the 16th century the law forbade the smelting of iron in England (Ritchie, 1920) and this forced the iron-smelters across the border and into the Highlands where there was still a good supply of timber. This was probably the main cause of the devastating forest clearance which continued for the next two centuries.

<u>18th century</u>. Many events of great importance took place in the 18th century. Of the earlier years of this period Darling (1955) has this to say of the north-west Highlands: "The cattle husbandry and persistence of the forests were reasonably compatible and even complimentary, for the cattle received shelter from the forest and the trees benefited from the light cropping of the herbage floor, from the browsing and the manuring. Regeneration was apparently sufficient for the continuance of the forest, and there was apparently some management of regenerating areas." But Darling also points out the reason for this; the cattle/sheep ratio was unity. He goes on to say that the older definite system of herding cattle on middle heights of hills in summer and bringing them to the shelter of woods in winter safeguarded the regeneration of woodland growth. The summer resting period for the herbage and uninterrupted growing season for the trees was essential to this system, for the woodland floor needed the herbaceous growth to maintain amelioration of the podsol. Summer grazing and treading would have depressed this herbaceous layer. So it seems that before the 18th century the forests were used fairly reasonably in the north-west Highlands.

However, with the construction of roads after the rebellions of 1715 and 1745 the Highlands became more accessible with the result that exploitation of timber was made easier. Soon, conditions became ideal for the rapid spread of sheep farming from the Lowlands. An increased population after the '45, a scarcity of food and the ever-present fear of famine are considered by Symon (1959) to be the initial causes of emigration from the Highlands. The first condition, therefore, was that there must have been many untenanted farms. Secondly, there were no wolves, as according to Darling (1955), the last one was exterminated in 1743. Thirdly, and probably most important, there were now large areas free of trees which would make excellent, fresh pastures for sheep. The opportunity was taken. Sheep farming spread rapidly. Darling (1955) records that before 1760 the first sheep farmers crossed the Highland line into the hills of Dunbartonshire. By 1782 they had reached Ross-shire. In 1790 the occupation of Argyll and Perthshire was completed. Sutherland and Caithness were reached in the last few years of the century, by which time sheep farming provided the main impetus for evictions and emigration (Symon, 1959). However, the same authority also points out that cattle were still being reared in large numbers throughout the time of the Highland clearances.

There were great improvements in agriculture and forestry during the 18th century. New methods of farming were introduced together with new crops, one of which was the turnip. By 1750 turnips were used as winter food for stock (Franklin, 1952) and therefore it became possible to keep many more beasts through the winter. There was also a great deal of tree planting carried out in this century and there seems to have been a marked appreciation of woodland for combined shelter and grazing. Anderson quotes Farquharson (1767) from his survey of the north side of Loch Tay, Perthshire, as saying that there was good grazing ground full of bushes and scattered hazel and alder. Woodlands were quoted as being fine shelter and pasture and on the bare hilltops shelter for cattle was recommended. There appears to have been some management in this area, for it was mentioned that tenants were prohibited from pasturing cattle within the fences of the woods for the first five years after they were cut. Anderson records an instance where in 1776 a gentleman in the Highlands of Aberdeenshire saved 500 cattle by wintering them in his woods, cutting down each day as many pine branches as would last a day, for the beasts to browse on the needles and twigs. In this connection it is mentioned that sheep eat and thrive on such food and upon young shoots of fir.

<u>19th and 20th centuries</u>. Land in the Highlands continued to be converted into sheep walks in the early years of the 19th century with evictions and emigration still taking place. But it seems that woodland had become valuable for grazing purposes as Anderson quotes many advertisements from papers of the time offering plantations or coppice-wood for grazing. Presumably it was the early bite obtainable in these woods that was greatly coveted as well as the physical benefits of shelter to the stock which would help to bring them through the winter.

Singers (1803) is mentioned by Anderson as having recommended two kinds of shelter plantations for sheep. One kind on the lower ground, fenced with stones, to shelter the ewes in April and another on the ridges for protecting the sheep in snow drifts and giving shelter in cold weather. Anderson quotes Singers further, saying that Highland woods are gradually disappearing to make room for sheep, a practice which he considers absurd by his remark: "To destroy the woods for the purpose of making room for sheep, is much the same kind of policy as it would be to destroy the buildings of a city, to make room for more inhabitants." Nevertheless, Ritchie (1920) records that in 1813 there was a great fire in Glen Strath-Farer in which 12 miles of pine, birch and oakwoods were burned to <u>improve</u> the sheep pasture. Alexander Sage, Minister of Kildonan in Sutherland, wrote in 1809 that the woods have been naturally decaying for the last 200 years and he attributes this to severe frosts and snowstorms in April and May. He remarks that it is bad for cattle-rearing and pointed out that the inhabitants used to out-winter cattle in the woods and were able to market them early in summer but now the beasts have to be housed at the beginning of November and are only just kept alive through the winter on straw. Finally, he complains that heath now occupies the land where fine, strong grasses used to grow (Anderson). Perhaps this was a result of clearing the deciduous trees (probably birch and oak) to "make room for sheep". Without the beneficial litter of these trees, strong and rapid leaching would occur giving rise to an acid soil and consequent colonisation by heath species.

It is interesting to note the observations made by

Walker (1808) as quoted by Anderson. He says that where there are woods or coppice, the herbage should be preserved for the winter. The cattle should be excluded from these places during the summer for they only abuse the herbage by trampling and dunging. It is not food that is sought in summer, but shade. Walker also mentions that leaves of ash, elm, oak, birch, alder, hazel and especially of certain willows are not only nourishing but wholesome and recommends their collection and storage for use as fodder. In addition, Stephens (1891) recommends Whin (Ulex europaea) and broom (Sarothamnus scoparius (L) Wimmer syn. Cytisus scoparius L.) as winter foods for cattle, sheep and horses, saying that cattle and horses take to it readily but sheep do not eat it willingly except when there is snow on the ground. Stephens also has this to say of Scots pine foliage as a food for sheep: "Where a Scots fir plantation is near the haunt of sheep, these need not starve, even in a snowstorm; for a daily supply of sprays, fresh cut from the trees, will support them as heartily as hay alone; and if hay is given along with the fir leaves, they will thrive better than on either alone."

In the first half of the 19th century the coppice woods in Scotland, according to Anderson, received some protection from animals. It was the practice to keep cattle out of coppice from 5-7 years after it was cut, but many authorities considered this to be too short a time. Other periods quoted are from 7-9 years and 8-12 years.

But by mid-19th century the charcoal and tan-bark industries had declined in importance and the existing coppice woods of oak and birch ceased to be economic. Protection against cattle and sheep was therefore unnecessary and farmers used these areas for out-wintering their stock, a practice which still continues to-day wherever such woodland remains.

With a lack of management and constant use these areas have been gradually disappearing and continue to do so. The remaining woodlands of this type cannot last much longer because continual grazing prevents regeneration. If these areas are of value for out-wintering stock, and there are indications that this is so, those concerned must decide whether to perpetuate this tree-cover or be content to see it disappear, for the longer such a decision is left the more difficult will it be for any remedial action to be carried out successfully.

CHAPTER 2

FOREST GRAZING IN OTHER COUNTRIES

It is of interest to know how this problem of forest grazing is resolved in other countries of the world where there is a demand for multiple land use, and the following have been selected because in every one the question has been extant for a very long time, much research has been carried out, and hence much has been written about the subject.

1. United States of America

Development. In most countries where the population is low and land plentiful, resources are used wastefully. Such was the situation in America in the 19th century, when the public range and allied resources were threatened with destruction. So in 1891 Congress authorised the creation of Forest Reserves to develop and preserve the forests, their timber and other resources (Sampson, 1923). This Act, however, specifically stated that sheep were to be excluded from using the ranges. Numerous and vigorous protests were made by sheep owners against this policy and after a Federal Investigation had been completed it was decided that total exclusion of sheep and the excessive limitations placed on horse and cattle grazing in some of the reserves was unjust (Sampson, 1923). Consequently, the grazing policy of the forest reserves was liberalised but an Act of 1897 empowered the Federal Government to issue rules and regulations for adequate control of livestock in these areas. According to Stoddart and Smith (1943), the Forestry Division of the U.S. Department of the Interior managed the reserves until 1905 when they were transferred to the U.S. Department of Agriculture under the control of the newly established Forest Service.

This transference of control to the Forest Service was of importance as far as the rehabilitation of state forest land was concerned, for soon after this Sampson (1952) reports that grazing fees were being collected for the first time, while Stoddart and Smith mention that with the change in name of the "forest reserves" to "national forests" in 1907 came the beginning of federal grazing administration.

The levying of fees for livestock grazing on national forests must have been a controversial issue at this time for Sampson (1952) records that in 1911 the U.S. Supreme Court rendered an affirmative decision for the collection of such fees. Again, in 1926, Smith writes about stockmen clamouring for the control of grazing on national forests to be transferred from the government to industrial organisations. Defending the existing policy he mentions that this would be tantamount to creating perpetual legal rights in the national forests which he strongly opposed. Also at this time the Secretary for Agriculture proposed new legislation to recognise grazing and utilisation of forage as an important and permanent use of national forests, together with rules and regulations for controlling such use. This was strenuously opposed by the Society of American Foresters, representing the foresters of the U.S., as can be seen in their Majority Report of the Committee on Grazing, 1926. Basically, they wanted to avoid such a situation as exists in much of Europe today, of legal rights to graze within state forests. Their fears are crystallised out in their main recommendation which states ".... that the principle of no property rights or easements within the National Forests shall ever be granted for grazing livestock within their boundaries and that such grazing shall never be permitted except upon absolute authority of the Secretary to regulate and terminate it at his discretion." A compromise seems to have been reached, for the present grazing policy in the U.S.A. corresponds very closely to the one proposed at this time by the Secretary for Agriculture, though the Society of American Foresters must have pressed home their recommendation on "rights", as Stoddart and Smith mention that even though grazing privileges in the national forests are paid for, they are not regarded as rights that individuals may exercise apart from authorisation of the governing agency.

This brief historical review is significant because it shows the development of forest grazing: after accepting the fact that forestry and grazing must be reconciled on the same area over much of the forested land, control of the grazing in national forests was vested in the Forest Service and by learning from the experience of European countries, it was decided that multiple land use could only succeed if grazing was strictly controlled and not allowed to become a right or easement.

Location and Characteristics of Range Land.

That region of the U.S.A. to the west of, roughly, the 100th meridian, is called "Range Land" and is characterised by low precipitation and soils too shallow, rocky or alkaline for successful crop production. Consequently the two main forms of land use are forestry and the production of store livestock. While each is practised to the exclusion of the other in some regions, there is a vast area on which forestry and grazing are co-dominant. Wooten (1955) quotes a figure of 606 million acres as the total area of forest and woodland in the United States. Of this, 457 million acres are classed as commerical and the remaining 149 million as non-commercial forest. The ownership of the commercial forest area is divided up as follows:

	million acres	%
National forests	73.5	16
Other federal	15.4	3
State, county and municipal	27.1	6
TOTAL in public ownership	116.0	25
Private farm	135.3	30
Private industrial and other	205.9	45
TOTAL in private ownership	341.2	75

Thus 75% of commercial forests are privately owned and 25% in public ownership. Hawley and Stickel (1959) are doubtful whether as much as one quarter of the commerical forest area of the U.S., if fully stocked, would carry forage of commercial value. Yet the same authorities mention that nearly 54% of commercial forest is grazed plus another 88 million acres, or 59%, of non-commercial forest, the whole amounting to 55% of the total area of forest and woodland in the United States, with a lion's share in private ownership. The federally-owned lands are administered either by the Bureau of Land Management of the Department of the Interior or the Forest Service of the Department of Agriculture.

As was mentioned earlier, the chief limiting factors to growth are shallow soils and low precipitation. Of the area to the west of the 100th meridian, 45% receives less than 15 inches of rainfall a year and a further 30% receives only 15 to 20 inches. On the seasonal distribution of the precipitation depends the season of use of the various types of range.

Stoddart and Smith recognise nine major range regions having similar vegetation, climate and range practices. Only five out of the nine contain trees and shrubs.

The Intermountain shrub region lies between the Rocky Mountains and the Sierra Nevada and Cascade Range. Precipitation tends to be more abundant in the non-growing season and winter temperatures are low, resulting in a brief spring growing period. The shrubs are of the semi-desert type and the season of use is determined by the local forage species, but is mainly during the spring/autumn and winter months.

The Southern desert shrub region in the southwest of the U.S., consists of xerophytic shrubs. Annual precipitation, reaching a maximum in late summer, is 3 to 15 inches, with an evaporation rate of 120 to 130 inches a year. Because of the uncertainty of the rains, long droughts and lack of water for the stock, this range is used for only short periods at a time and sometimes not at all. However, after a heavy period of rain when there is an abundance of forage it is impossible to obtain enough stock to utilise the growth. It is essentially winter range for sheep.

The Chaparral region is sub-divided into three types.

(i) The Californian chaparral, where there is a very heavy winter rainfall and high winter temperatures, giving rise to a winter growing season, is very inferior range, used mainly during emergencies, such as drought.

(ii) The Oak type, covering large areas in the West, consists of many species of deciduous and evergreen oak. Spatial distribution varies from a very dense brush stand where grazing is difficult but still possible, to open savanna-like woodland, the former being spring-autumn range and the latter yearlong.

(iii) The Mountain brush type, restricted in area to narrow strips between the coniferous forest and grassland, is probably a sub-climax to coniferous forest, especially after burning. This range type is extremely variable in soil, climate and vegetation though it is all used during the spring or autumn.

The Piñon-Juniper region is characterised by low-growing, non-timber producing conifers. Grazing is therefore the chief land use. It is found mainly on the southern ranges at elevations between 4,000 and 6,000 feet and consists of a pine/juniper mixture. Rainfall is generally less than 16 inches per annum and temperatures are high. It is ideally suited for spring (lambing) range.

The Northern coniferous forest region lies mainly in and around the Rocky Mountains. There is extreme variation in vegetation, for rainfall varies from 15 to 100 inches a year, altitude from sea level to 12,000 feet and temperature from frost-free to extremely cold. The main tree species are Pseudotsuga, Pinus, Picea and Abies. Within the region there are four sub-regions and many zones within these sub-regions.

(i) Southern Rocky Mountain coniferous forest. Being the southernmost of the forested lands, it has a longer growing season, higher temperatures and lower precipitation than most, even though elevations are from 6,000 to 12,000 feet.

Ponderosa pine forest is the most important type, and is usually open forest, providing abundant forage under the trees and in open meadows. The Douglas fir - Engelman spruce type is generally too dense to support any grazing.

Cattle and sheep use this range, generally for 4 to 6 months in the summer, though some forests are grazed during the milder winter months.

(ii) Central Rocky Mountain coniferous forest. Grazing in this sub-region is of equal importance to timber production. Precipitation is from 15 to 40 inches a year, mostly as snow, and the climate is characterised by short summers, with a two to three month growing season. It is a very important part of the western range as large numbers of cattle and sheep use the area. There are four types.

(a) Ponderosa pine zone. Many animals are overwintered in this zone. It supports a variety of grasses and shrubs which are of great value to grazing animals.

(b) Douglas fir - Aspen zone. Although at lower elevations the Douglas fir grows in open stands in which there is

<u>Plate 1.</u> Open coniferous forest, with Douglas fir dominant, and an undercover of grazeable grasses and herbs.

(Stoddart and Smith, 1943)

<u>Plate 2.</u> Aspen dominates thousands of acres in the western mountain ranges and is underlain by valuable forage plants which form some of the highest producing ranges in the West.

(Stoddart and Smith, 1943)

plenty of forage (Plate 1), they become denser at higher elevations and grazing is precluded. Most of the grazing occurs in the aspen type which usually grows in open stands under which there is a good and plentiful supply of forage (Plate 2).

(c) Spruce - Fir zone. The trees usually grow in clumps interspersed with open parks or broad meadows, providing good grazing for sheep and cattle for a short period during the summer months (Plate 3).

(d) Alpine - Tundra zone. This occurs above the timber line, at 11,000 to 11,500 feet. The lower regions of this type consist of scrubby, stunted trees. Due mainly to steep topography, but also to the severe climate, this zone is used by cattle and sheep for a very short time in summer.

(iii) Northern coniferous forest. In the northern area timber production is of primary importance but over the remainder forage is produced under open stands of timber (Plate 4). Season of use is in the summer only, as the winters are bitterly cold, with heavy snowfalls.

(iv) Northwestern coniferous forest. This type is of little importance for grazing as it is the main timber producing area of America.

To summarise: In the U.S.A. grassland covers 38% of the area, desert shrub 14% and forest 48% (Sampson, 1952). Livestock are usually wintered in the grassland areas (plains and prairies) or intermountain and southern desert shrub regions, moved to the piñon-juniper and chaparral types during the spring, and then gradually ascend through the various coniferous zones as summer progresses. An exception to this is in the eastern Rockies where over-

(Stoddart and Smith, 1943)

Plate 3. Spruce - Fir zone, showing the open meadows and parks between clumps of spruce and fir.

(Stoddart and Smith, 1943)

Plate 4. In spite of poor forage conditions cattle graze through the dense coniferous forest.

wintering takes place on the slopes of the Ponderosa pine zone.

Range Practices

Sampson (1952) enumerates the objects of public range-land administration as:

(i) To ensure sustained forage production and maximum grazing use based upon estimation of grazing capacity, establishment of rational grazing periods, and selection of the most suitable kind of livestock for the plant cover, soil and topography; (ii) to obtain a balanced use of the resources by preventing one use from preventing undue damage to the other resources; (iii) to stabilise the livestock industry by recognising the eligibility of permittees, issuing long-term permits and granting maximum freedom of operation; (iv) to render technical assistance to the grazier and prevent inequality among permittees on Federal range.

The work entailed in achieving these objects is well described by Stoddart and Smith (1943) and Sampson (1952). Before any public range land is used a range survey is carried out so that a range inventory can be compiled, resulting in the formation and implementation of a range management plan.

A map is drawn up recording the main forage types and sub-types, together with the location of any streams, springs, obstacles to livestock and other important topographical features. Information is collected as to the composition and density of the vegetation, the suitable stock for grazing these areas and the percentage ratio of each important forage species to the whole plant cover.

From this field data the grazing capacity of the range can be worked out.

The grazing capacity of range land is an important factor and can only be assessed after much preliminary investigation, as it involves the determination of a "forage acre", which is itself dependent on a "proper-use factor". Sampson (1952) defines the term "proper—use" as "the degree of grazing that an individual species, or the total palatable cover of a range area, may endure without damage to it or the soil", but Stoddart and Smith extend this definition to include the prevention of damage to <u>any</u> of the land resources, and not just vegetation and soil. The "proper-use factor" is defined as the percentage, by weight, of palatable herbage that can be grazed safely in perpetuity. There are several methods of calculation but the proper-use factor can vary for the same species according to the type of livestock being grazed, season, climate, associated species, past grazing use and locality factors.

Once the proper-use factor has been determined it is a simple process to calculate the "forage acreage". A forage acre is defined by Sampson (1952) as "a hypothetical acre with a 10/10 density of forage that can be utilised to the limits of the physiological endurance of the vegetation". Thus a forage acre will only be exactly equal to a surface acre of vegetation if this vegetation has a density of 10/10, is all palatable to the livestock about to graze it, and is completely accessible and utilisable. As these conditions rarely prevail, the forage acreage is less than the actual acreage, and is calculated thus:

Forage acre = Total av. density of veg. type x Proper-use factor of veg. type x Acreage of veg. type

The grazing capacity, defined as the number of animals that can be maintained on a unit area for a specified period of time without injury to the range or other resources, is finally arrived at by dividing the number of forage acres by the forage-acre requirement, the latter being the number of forage acres, or fraction thereof, required to support a mature grazing animal for a specified period without injury to the range resources. This has to be determined empirically. Knowing the number of pounds of forage required per day per beast to keep it in good condition, the acreage which will supply this amount is worked out by one of several methods and is known as the forage-acre requirement.

These definitions and calculations can be summarised:

Density of vegetation type is estimated in tenths.

Proper-use factor (PUF) = Percentage palatable forage which can be used safely in perpetuity.

Forage acre = Density of veg. type x PUF of veg. type x acreage of veg. type.

$$\text{Grazing capacity} = \frac{\text{Forage acres}}{\text{Forage-acre requirement}}$$

<u>An Example</u>:

From a range survey the following information is obtained:

Density of vegetation type = 6/10 or .6

Proper-use factor of this vegetation type = 50%

Acreage of vegetation type = 80 acres.

Forage-acre requirements are - 0.6 forage acre/month for cattle

0.2 " " " " sheep

No. of forage acres of veg. type = .6 x .5 x 80 = 24 acres

Grazing capacity for cattle = $\frac{24}{.6}$ = 40 cow months

Grazing capacity for sheep = $\frac{24}{.2}$ = 120 sheep months

(N.B. For simplicity this example assumes the PUF of the vegetation to be the same for cattle and sheep, but in practice this is usually not so.)

Stoddart and Smith mention that where game exists on range land, the grazing plan should be adjusted to allow controlled use by these animals. The same authorities also advocate adjusting livestock numbers each year to suit the condition of the vegetation. In years when there is plenty of forage, an increase in herd numbers to utilise this extra forage can be effected by: (i) keeping steer calves another year and (ii) increasing the cow herd by retaining or buying in heifers. In bad seasons, when food is short, a decrease in livestock numbers is advised in order to prevent damage to the vegetation by overgrazing. Theoretically, incomes should remain the same due to the fewer beasts being of better quality. Suggested methods of adjusting livestock numbers are: (i) sell beasts early enough to ensure sufficient feed for the breeding herd; (ii) sell cattle whose meat value is near maximum; (iii) sell weaned calves and old or thin cows which would be expensive to maintain; (iv) sell heifers that would not contribute to building up the herd; (v) sell inferior or shy breeding cows.

In the southeastern range states controlled burning is carried out in the Longleaf, Slash and Loblolly pine forest to keep the understorey open and also to improve the forage.

But it can also be used simultaneously as a silvicultural tool, for Sampson (1952) describes how these tree species can be favoured or eliminated depending on the frequency of burning. Other techniques such as seeding cut-over timber land and the use of rotational, deferred and deferred-rotation grazing are employed to improve or maintain the grazing on range land.

The Forest Service issue grazing permits and collect grazing fees. Permits are of seven types:

(i) term, usually issued for a ten year period;

(ii) annual;

(iii) temporary;

(iv) free, issued to genuine settlers for not more than ten animals used for domestic purposes, and also to certain other specified people;

(v) on and off, issued only where permitted livestock have to be moved between national forests and adjoining outside range;

(vi) private land, issued when the government is compensated for use of forest lands by the use of private lands of equal value, and when lands are released to the government for exclusive administrative control of the grazing use;

(vii) crossing, where livestock have to cross any portion of a national forest for legitimate purposes.

Any resident of the United States can apply for a grazing permit but in most areas, because the demand for forage greatly exceeds the supply, a system of preferences exists so that those people who can make the best use of the resources obtain permits first. In addition to obtaining permits from the Forest Service, grazing fees have to be paid to this Department. On national forests the fees are related to the value of the forage and therefore as economic factors change, grazing fees may vary accordingly.

Of the income obtained from grazing on national forests, 25% is returned to the states in which the forests are located for expenditure on roads and schools, 10% is retained for expenditure on national forest roads and the remaining 65% is passed on to the U.S. Treasury (Sampson, 1952).

It is stressed by Stoddard and Smith and Sampson (1952) that although grazing priviledges are paid for, they are not regarded as vested property rights or easements, and may not be exercised without the authority of the Forest Service.

2. India

The cow and bull are sacred animals in India and are not slaughtered. As a result the country is vastly overstocked with cattle, mostly of poor quality due to promiscuous and uncontrolled breeding. Whyte (1952) quotes a conservative estimate of Kay's that in 1946 India was trying to feed nearly 90 million cattle too many. The problem is aggravated because the effective grazing season is usually only four to five months a year, although it is now a normal practice to graze yearlong. As the fodder situation is so critical every type of food is utilised, including tree leaves, fruits and seeds.

There are three classes of forests; government, revenue and private. In 1947-48 11%, or 24.7 million of all cattle had access to government, mainly reserve, forests (Whyte, 1952). This becomes a serious problem partly because it is concentrated on the more accessible areas, such as forest fringes, village borders and around sources of water, and also because cattle have to be brought back to the village at night time, thus making it impracticable to graze beyond about a five mile radius from the village. Sometimes this problem is resolved by penning the cattle in the interior of the forests and moving them from one pen to another as the forage becomes used up. However, in forests that are too far removed from, or closed to, grazing, grass cutting is permitted because it helps to reduce the fire hazard. Whyte remarks that although grass cutting is preferable to grazing in all forests, it will not be practicable until the quality of the livestock is improved, because stall-feeding is worthwhile only for selected animals and not "for large herds of famished scrub cattle."

Grass in India is of poor quality, except during the short monsoon period (June to September) and there is little evidence that it can be improved by enrichment with legumes or that fertilisation is an economic proposition. Silage has been made from forest grass but the cost of collection is high due to the presence of trees.

Tree fodders are an important forest product in North India as the grass is useless in winter and if there is no hay or silage, leaf fodder is the only available food for six months of the year. In the inner Himalayas each farm has its own allotted broadleaved trees which are carefully preserved for lopping in a regular rotation, while in other areas lopping is permitted in fuel coupes prior to exploitation.

Forest grazing regulations

Whyte (1952) says: "Forest grazing, like forest burning, is a good servant but a bad master. In association with other biotic factors, grazing is often important in arresting ecological succession in forests and maintaining them at an economically valuable stage. It is, therefore, not correct to say that forestry and grazing are incompatible, but unlimited or uncontrolled grazing has no place in forest management."

The Indian Government, in formulating its new National Forest Policy in 1952 stated as one of the four vital national requirements "the need for ensuring sustained supplies of grazing." The fact that forest grazing takes place is accepted with the provision that it must be regulated as regards time and place, as well as the number of cattle allowed into the forest. The principles of Indian forest grazing policy are:

(i) continuous grazing of the same areas by large herds is detrimental to the forage resources and should be discouraged in favour of rotational grazing;

(ii) cheap forest grazing is undesirable because it allows too many cattle to be maintained in the forest leading to inadequate forage, decreased quality of livestock and thus further increases in numbers to compensate for the reduction in quality;

(iii) the introduction of a reasonable fee for the privilege of forest grazing is an obvious method of regulating and controlling this practice;

(iv) grazing must not be allowed in regeneration areas and young plantations before the seedlings are fully established; (v) grazing should be kept to a minimum in Protection forests.

Following these principles, forest grazing is organised on the basis of grazing permits, passes or licences, the price of which varies from state to state. These permits authorise the length of the grazing season and the extent of the grazing area. Essential domestic cattle are allowed to graze free or at concession rates and all others are charged at a higher rate.

There are various methods in operation in India for assessing the maximum number of cattle to be allowed into the different types of forest but Whyte points out that all the figures are at present rather arbitrary.

Legal provision is made for the closure of forest areas undergoing regeneration and also at varying intervals during a rotation. Whyte quotes as an example, teak on a rotation of 40 years, where the area is closed to grazing from 0-5 years, open from 6-20 years, closed again from 21-25 years and open from 26-40 years.

Closure is also legally permitted for improvement purposes. In these circumstances rotational, periodic or deferred systems of grazing are practised. Periodic grazing is used extensively and there are infinite refinements to this system, depending upon the intensity of management.

A simple example would be:

Section of forest to be grazed is first divided into three more or less equal sections, A, B and C. They are used thus:-

	Closed for the year	Monsoon season Open	Monsoon season closed	Open for remainder of year
1st year	A	C	A B	B C
2nd year	B	A	B C	A C
3rd year	C	B	A C	A B

Thereafter the cycle is repeated.

Grazing rights exist in India but these are commuted wherever possible.

3. Europe

(i) France

The fact that in December, 1954, a whole issue of Revue Forestière Française was devoted to the problems of the agro-sylvo-pastoral equilibrium in France indicates that this question is of some importance.

It is mainly in the mountainous regions of France, the Jura, Savoie and Haute Savoie, Alps and Pyrenees, that forest pasturage predominates, as climatic and edaphic factors dictate the form of land use. The climate is harsh and rigorous, and the soils usually shallow and rocky, with the result that a sylvo-pastoral form of land use has become established. This involves stock-raising and the

(Lachaussée, 1954)

Plate 5. Sylvo-pastoral equilibrium, High Jura, 1,300 m. Foreground: pasturage. Water cistern on right, mown grassland enclosed by wall on left. Middle ground: *pré-bois*. Background: Forest of Massacre.

(Lachaussée, 1954)

Plate 6. Commune of Prenovel, Jura, 900 m. A narrow, well-sheltered dell in the *prés-bois*.

production of milk and cheese for which adequate pasture land is required, while the forestry enterprise is equally important for its shelter and timber.

Plates 5 to 7 show the characteristic appearance of the majority of land used for forest pasturage in the mountainous regions. These "Prés-bois", or wooded-meadows, are a transition zone between true forest and pure grazing land. The trees, mainly spruce, fir, larch and beech, occur scattered individually over the area or in clumps of varying density, leaving well-sheltered "rooms" of pasture between them. This pré-bois, says Perrin (1952), is a system extensive and complex enough to merit a half-forestry half-pastoral utilisation. But he advocates the separation of the two practices by creating small woods, of one hectare ($2\frac{1}{2}$ acres) or less, for timber, and only allowing a few trees on the pasture for shade. Lachaussée (1954) is also in favour of concentrating forestry and grazing on different areas.

Poncet (1957) describes conditions in the Inspection of Briançon in the High Alps. Here European larch, at an altitude of 1,200 to 2,000 metres (3,950 to 6,550 feet), tends to form natural, fully-stocked high forest, which is dense and even-aged. 5,000 hectares (12,360 acres) of this forest type are grazed for two months during the summer by 1,600 cattle and 3,000 sheep, a stocking of one beast to just over $2\frac{1}{2}$ acres. The Uniform system of silviculture is practised together with the alterable allotment (floating periodic block of Troup (1928)) system of management wherever possible, though sometimes the group selection system is used. Regeneration is guaranteed by excluding

(Perrin, 1952)

Plate 7. Larch prés-bois, High Alps.

grazing on one third of the area for sixty years, after which it is grazed again for a period of 100 to 120 years and another third is enclosed for a sixty year period and so on.

Lachaussée (1954) mentions that Swiss livestock migrate to the alpine pastures in the French Jura for the summer months. The conditions and system of pasturage are probably very similar to those in the Swiss Jura.

(ii) Switzerland.

Rieben (1957) gives a good description of the sylvo-pastoral régime. The main features of the Swiss Jura are rolling contours, a harsh climate, a limestone sub-stratum and the typical wooded-pastures already described above (prés-bois). There are still 40,000 acres of this open to grazing. But Rieben points out that grazing in wooded-pastures prevents regeneration and favours the spruce at the expense of beech and fir. In general, he maintains that the mixed exploitation of the land results in a decreased quantity and quality of pastoral and forest products. The remedy suggested is to separate woodland from pasture land by judicious fencing, and then improve each type independently. When dividing the area up Rieben advocates doing this to leave strips or "curtains" of trees and shrubs on the meadows for shelter for the cattle and herbage. The final effect is one of large, lightly-wooded meadows, separated by blocks of woodland which are closed to grazing.

(iii) Germany.

von Dietze (1955) gives the distribution of German forest property (for 1949, in round figures) as:

	Million ha.	Million ac.	%
State forests	2.1	5.2	30
Forest owned by communes, foundations and co-operatives	2.1	5.2	30
Private forests	2.7	6.7	40

In all groups, operating ownership is the rule. Large forests are segregated from agricultural land, but it is typical for forestry and agriculture to be interdependent, with agriculture predominating, on woodland units of less than 100 hectares (about 250 acres), which accounts for 32% of all forests, and the combination becomes even stronger where the woodland unit is less than 50 hectares (about 125 acres).

Medium-sized agricultural holdings in hilly regions cannot yield a sufficient living without a certain amount of woodland. Here the woodland supplies fuel, timber for building and general farm maintenance as well as a surplus for sale. In addition, there is the advantage that seasonal demands on manpower and machinery are levelled out. In fact, the woodland is considered as a savings bank, which may supplement the agricultural income or provide for expansion of farm buildings. There is, therefore, a risk of bad forest management or over exploitation in these "peasant woodlands" but this is kept at a minimum by laws which regulate felling and forest practice in general, similar to the conditions involved in the Dedication Scheme in Britain. von Dietze mentions that instead of the usual haughty reproaches as to the inferiority of forestry as practised by the small farmer, better ways of advising them are worked out.

In hilly regions of the Black Forest, 800 to 1,000 metres (2,600 to 3,300 feet) above sea-level, von Dietze says that 50% and more of the land in farms is under trees and quotes a typical example from this region. A 50 hectare farm (about 125 acres) is run by a farmer and his family, with perhaps one or two hired labourers and he will have 5 hectares (about $12\frac{1}{2}$ acres) under grain, potatoes and fodder crops, 20 hectares (50 acres) of grassland and 25 hectares (about $62\frac{1}{2}$ acres) of woodland.

It is not surprising, therefore, that von Dietze concludes that the segregation of forestry and agriculture in hilly regions would lead to the disappearance of the latter.

But Ager (1957) maintains that in the High Bavarian Alps yields from the mountain and wooded pastures are kept low by the haphazard sylvo-pastoral exploitation and favours the separation of forest from grazing land. This, he observes, is made very difficult by the present complicated laws governing the rights of grazing within the forests.

4. Scandinavia

(i) Norway.

The farmers of Norway "... are forest-minded to a degree unknown in Britain." (Mutch, 1958). More than half the forest land of Norway is owned by farmers and these farm forests are managed as an integral part of the farm, without which there would not be a reasonable standard of living. Farm-forestry is traditional and any alteration in this combined ownership of farm and forest would have far-reaching effects on the judicial and social structure of the country (Eskeland, 1955).

Forest ownership breaks down thus (Skinnemoen, 1957):-

Private ownership	71%
Foundation, collective and company	10%
Common forests	5%
Community	3%
State	11%

In northern Norway, where the State owns considerable forest and rough land, farmers are entitled to grazing rights and timber, as is the case in the common forests. This is gradually being abolished, according to Eskeland (1955) as a system of re-allocation of land proceeds.

Forest grazing practice does not appear to vary throughout the country, though the tree species and the effect of grazing alters from west to east.

The farms are situated on the low ground where permanent pasture predominates. Above the "in-bye" lies a belt of productive forest. In the west this is of Scots pine with a ground vegetation of blaeberry, crowberry and some heather. Above this is birch, and together with the land above the forest limit, which is relatively fertile by Scottish standards, is used as summer grazing for cattle and sheep. The number of stock kept is limited by the amount of winter keep, for both cattle and sheep have to be kept indoors for four or five months in the year. Grazing intensity is therefore light in the summer grazings and damage to the forest is slight, apart from the immediate vicinity of the shielings, which are treeless due to the combined effect of firewood cutting and grazing. No fences separate the summer grazing birch woods from the productive forest; herding is effective in preventing straying (Mutch, 1958).

Mutch (personal communication) observes that conditions differ slightly in eastern Norway. Scots pine generally grows on the lower hill slopes, giving way to Norway spruce to the tree limit, where it is mixed with birch. The grazing above the tree limit is poor and summer grazing tends to be concentrated in the upper spruce-birch forest. If grazing is excessive a depression of the tree line may occur.

Skinnemoen (1957) mentions that although forests provide adequate grazing, this is not sufficiently nutritious to satisfy the demands of modern cattle breeding, and advocates the separation of forest and pasture. He also records the existence of a Forest Protection Act which allows cattle to be excluded from grazing in the forests at certain times of the year and goat-grazing to be entirely forbidden.

(ii) <u>Sweden</u>.

Swedborg (1955) records the latest figures for forest ownership in Sweden (Agric. survey, 1951):-

State and other communities	25%
Corporations	25%
Private	50%

In the first category are included parish-owned common grounds and common forests. Of the forest which is privately owned most belongs to peasant farmers.

Giöbel (1960) describes how, up to the end of the 19th century, the predominant type of pasture was one covered with trees and bushes but that after the first world war this dual-purpose system of forestry and grazing was found to be unsatisfactory for highly productive dairy cows. The tendency thereafter was towards a single form of land use. But the natural, wooded pastures still predominate in forest areas, being used for dairy cows, beef cows and young stock because, according to Giöbel, farmers are generally reluctant to use the limited areas of arable land for pastures when they have access to ample natural pasture ground. The same authority observes that little work has been done to determine the merits of mixed utilisation and it is justifiable, at present, to use the natural pastures for the primary purpose of grazing, provided that they are well managed.

Conclusions

In most countries the season of use of forests for grazing is during the summer months when the growth of forage is at or near a maximum. With adequate forage cattle, and sheep to a certain extent, tend not to browse on trees or foliage. Moreover, because much of the forested land is used in summer for the primary purpose of grazing, shelter for livestock is of less importance than the production of good quality herbage. Consequently, the tendency in Europe and Scandinavia seems to be towards a separation of the existing dual form of sylvo-pastoral land use wherever possible.

Conditions and requirements in Scotland are the exact opposite. The winter climate is harsh and therefore the first requirement of our stock raisers is shelter during the winter months. This means that if woodlands are to supply this shelter at a time when natural forage is at a minimum they will be predisposed to browsing damage.

The product of the American Range States is similar to that of Scottish hill farms, namely store livestock. But the similarity ends there. American National Forests are not as intensively managed as Scottish forests, or indeed most European ones. This factor probably contributes greatly to the success of their forest grazing policy. In addition, livestock can be moved from one climatic zone to another as the season demands, which again is not possible in Scotland. Strict control of forest grazing policy is vested in the American Forest Service, a task made easier by the fact that there are no grazing rights or easements within the forests, as is the case in much of Europe and India.

The distribution of forest ownership is also an important factor to the success or otherwise of a dual form of land use. The American grazing policy described in this chapter applies solely to federally-owned forest land, amounting to only about 16% of the total forest area. That it is successful over this area is due partly to the fact that the Forest Service has absolute control over the grazing, while on all other land they can act only in an advisory capacity and have no power to control over-grazing. In Norway and Sweden, where most of the forests are privately-owned by forest-conscious farmers, the situation is very different. Forestry plays an integral and important part in agriculture and there are few instances of over-exploitation of forests. Scotland, however, enjoys no such tradition of productive farm-forestry, and farmers often neglect their forest land and may ultimately reclaim it for agriculture.

In general, one can conclude from this study that where forest grazing is necessary it need not be inimical to good forestry practice provided it is strictly controlled by the forester.

CHAPTER 3

THE WOODLAND MICROCLIMATE

1. Radiation. Solar radiation, apart from being the source of energy for plant metabolism, is responsible, either directly or indirectly, for differences in temperature, humidity, evaporation and transpiration (Kittredge, 1948).

A great deal of solar radiation is lost before reaching ground level due to reflection from clouds and atmospheric absorption and scattering. Further losses occur at ground level from long wave radiation, reflection, evaporation, convection and conduction, the balance being supplied to the ground, though the amount of radiation incident on any particular site is dependent on latitude, altitude, degree of slope, aspect and season of the year. At night, heat is lost through radiation and evaporation so that the cooler and heavier air layers lie nearest the ground. But vegetation modifies this system of heat exchange, both by day and night (Geiger, 1957), and the upper surface of the vegetation, in this case the forest canopy, effectively becomes a new radiating surface. This has a marked effect on the temperature gradient within woodlands, as will be shown in the next section.

The intensity and type of light reaching the forest floor is very variable. Geiger (1957) mentions that in general 80% of incident radiation is caught in the crown space, with less than 5% reaching the forest floor. But this obviously depends on the tree species forming the stand, its age and density, and also, where deciduous trees are concerned, the season of the year. Geiger gives a useful comparison of light intensities under different species in the following table:-

Tree Species (old stand)	Illumination on Forest Floor in % of Outside Illumination	
	Deciduous	
	Leafless	Leaves Out
Red beech	26 - 66	2 - 40
Oak	43 - 69	3 - 35
Ash	39 - 80	8 - 60
Birch	- - -	20 - 30
	Evergreen	
Silver fir	2 - 20	
Spruce	4 - 40	
Scots pine	22 - 40	

The type of radiation penetrating to the forest floor differs markedly to that which reaches the forest canopy, for the latter has a filtering effect and according to Geiger the spectral composition of forest shade is not the same as shade cast by a solid object, such as a stone wall. Forest shade is deficient in blue light and particularly rich in infra-red. This may account for the observation that herbage within a stand is less palatable than that outside it. here?

2. <u>Temperature</u>. (i) Air temperature. As mentioned in the previous section, vegetation affects the heat régime near the ground and because of the relatively large size of trees and shrubs compared with herbaceous vegetation this effect can be very pronounced.

Under the crowns of a forest stand there is a deep body of air whose properties are conditioned by the stand. This is the trunk climate. The trees have the effect of de-activating the ground under them as a radiating surface, and raising it to the crown level which thus assumes the radiating properties of open ground. It is in the crown space that radiation is absorbed and emitted, the free wind retarded and water given off to the air as it is on open ground (Geiger, 1957). This property is of great importance as it results in a more equable climate within a stand.

Geiger shows that in a 24 metre high (79 feet), 115 year old oak stand, interspersed with 40 to 50 year old beech in the pole stage, the temperature range 3 metres (10 feet) above the forest floor on a calm, summer day is just under 10°C (18°F). During the night, minimum temperatures are in the tree canopy and maximum temperatures on the forest floor, the position being reversed during the day. The reduced temperature range results from a slight increase in daily minimum temperatures and a slight decrease in daily maxima. This prevails throughout the year to give lower summer temperatures but higher winter temperatures. Toumey and Korstian (1947) give an interesting comparison of temperatures under forest conditions in Europe.

Period	Differences in air temperature within forest compared to open ground. °F.			
	Eastern France	Mountains of Alsace	Bavaria	Eastern Prussia
Feb. - April				
Av. of daily max.	-1.44	-1.98	-0.90	-1.26
Av. of daily min.	+1.44	+3.42	+0.36	+0.18
Mean temp.	0	-0.72	-0.54	-0.54
May - July				
Av. of daily max.	-5.76	-4.50	-3.96	-2.52
Av. of daily min.	+2.16	+3.42	+1.98	+0.90
Mean temp.	-1.80	-0.54	-1.62	-0.72
Aug. - Oct.				
Av. of daily max.	-4.68	-3.42	-5.76	-2.88
Av. of daily min.	+2.34	+4.32	+2.88	+0.36
Mean temp.	-1.08	-0.36	-1.44	-1.26
Nov. - Jan.				
Av. of daily max.	-1.62	+1.62	0	-0.54
Av. of daily min.	+1.08	+3.06	+2.16	-0.36
Mean temp.	-0.18	+2.34	+1.08	-0.36
Whole year				
Av. of daily max.	-3.42	-2.26	-2.70	-1.80
Av. of daily min.	+1.08	+3.60	+1.80	-0.36
Mean temp.	-0.72	+0.72	-0.54	-0.72

While this table shows that the mean annual temperature within a forest is reduced, the daily minimum temperatures are increased by an average of 2°F. Figures quoted by Kittredge (1948) shows mean minimum temperatures in January in a variety of American forests ranging from -0.1 to +6.0°F difference from open ground, again the average being about +2.0°F.

Geiger cites an experiment by Amann carried out in the Anzing-Ebersberg forest on the Bavarian plateau. The experimental area of 0.88 hectares (2.2 acres) consisted of an open stand of birch, 32 years old, average height 11 metres (36 feet), under which were 14 year old spruce between 0.8 and 1.5 metres high ($2\frac{1}{2}$ to 5 feet). On one side of the birch stand was open, level ground which served as a control while on the other was an old spruce forest. During May, 1927, Amann measured the temperature during the night in these three areas, at a height of 25 cms above ground level, and the results showed that for the average of the 11 coldest May nights the temperature in the stand of open birch was higher than that in the open by $4^{o}C$ ($7.2^{o}F$) and in individual cases was as high as $6^{o}C$ ($10.8^{o}F$). Differences of the same magnitude were also observed in the old spruce stand.

The diurnal course of temperature follows a fairly regular pattern. At sunrise the lowest temperature is in the crowns of the trees and the forest floor is the warmest place. As the sun continues to rise warming takes place above the crowns and after several hours the crown space begins to warm up, the forest floor still remaining at a lower and relatively constant temperature. Only after about three hours does the temperature in the lower layers of the forest begin to rise and this reaches a maximum around 2 o'clock in the afternoon. Thereafter cooling takes place and minimum temperatures are reached in the early hours of the morning.

(ii) Soil temperature. Toumey and Korstian (1947) and Kittredge (1948) show that soil temperatures under a forest cover are generally lower than in the open during spring and summer and higher in autumn and winter. This effect is most marked near the surface and decreases in depth, though the rate of change is slower within a stand. Kittredge also mentions that forest soil temperatures are lower than forest air temperatures in summer but higher in winter.

Radiation from forest litter is less than that from bare soil and thus freezing of the soil is retarded.

3. <u>Humidity</u>

Geiger (1957) gives an account of the diurnal rhythm of humidity within a forest. Before sunrise humidity is high throughout the stand. Dew, when it forms, is deposited on the upper surface of the crowns. After sunrise the crowns begin to dry out and humidity decreases in the crown space but remains high in the trunk space (curve T_1, Fig. 1). Later, as the sun gets higher and the wind usually freshens, the decrease in humidity penetrates into the interior of the stand to reach a minimum around mid-day (curve T_2). As cooling takes place within the forest during late afternoon and evening the transference of water vapour from the ground becomes more effective and produces high humidities in the trunk space (curve T_3). At all times during the day and night the highest humidity is always to be found nearest the ground, as shown in Figure 1.

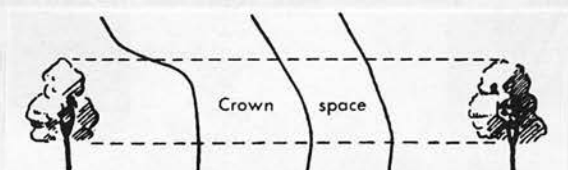


Fig. 1

Types of distribution of relative humidity within a forest. (after Geiger, 1957).

This diurnal effect is more marked in spring and summer than the autumn and winter (Kittredge, 1948).

4. Evaporation and Transpiration

(i) Evaporation. This depends upon the combined effect of humidity, wind, temperature, atmospheric pressure and radiant energy. Caborn (1957) states that in the absence of air movement, evaporation is closely related to the vapour pressure deficit and further, that temperature exceeds wind velocity in its influence on the rate of evaporation. But when temperature and humidity in an area are fairly uniform, evaporation is almost exclusively controlled by wind and the distribution of evaporation closely follows that of wind velocity. Nägeli (1961) shows that the rate of evaporation in a forest complex is closely proportional to the square root of the wind velocity.

One can conclude from this that evaporation rates within a forest are likely to be low, compared to open country.

(ii) Transpiration. Transpiration from the herbaceous layer within a forest will be affected by humidity, and therefore also temperature, and wind. Wind removes humid air from the proximity of the plant and thus increases diffusion through the stomata. But as it has been shown that under forest conditions, other things being equal, wind velocity is generally low and humidity high, transpiration rates will probably be low within the forest in comparison to external conditions.

5. Wind

One of the most important, and probably the most noticeable, difference between forest and open land is the change in wind velocity, which ultimately affects nearly all other climatic factors within the stand.

The theory of air movement over trees and shelterbelts and the processes which lead to a change in wind velocity are described succinctly by Caborn (1957) and will not be mentioned here.

Figure 2 shows the typical degree of influence of a forest on wind speed. A large reduction in velocity occurs in the crown space but towards the lower edge there is a slight increase, which reaches a maximum in the middle trunk space. Thereafter velocity decreases with a decrease in height. Geiger (1957) is in agreement with this. However, Kittredge mentions that variations to

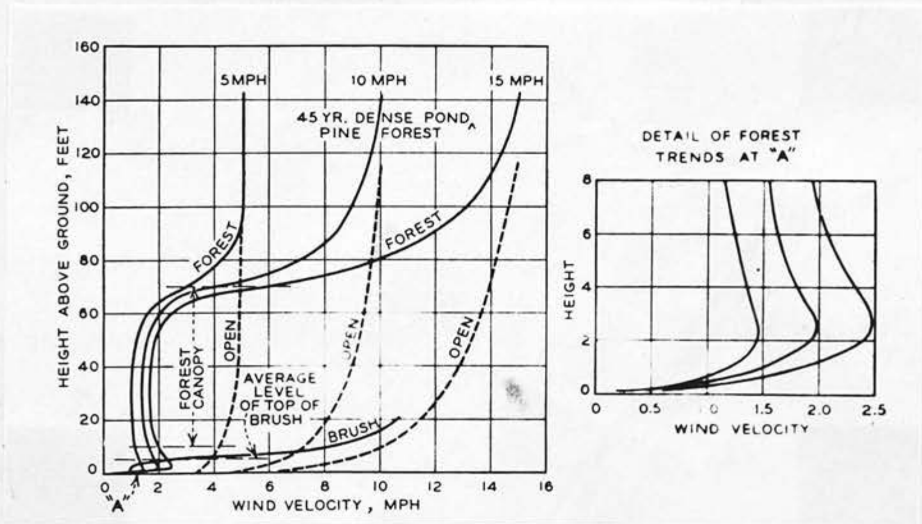


Fig. 2. Vertical gradients of wind velocities in the Shasta Experimental Forest, U.S.A.

(after Fons; Kittredge, 1948)

this pattern occur according to the height, depth, width and density of individual tree crowns and with the density of the stand and therefore also with age, size and species of tree.

Geiger shows that the tree species and season of year also influence wind speed. Figure 3 indicates wind speeds observed in a 24 metre high (79 feet), 115 year old oak

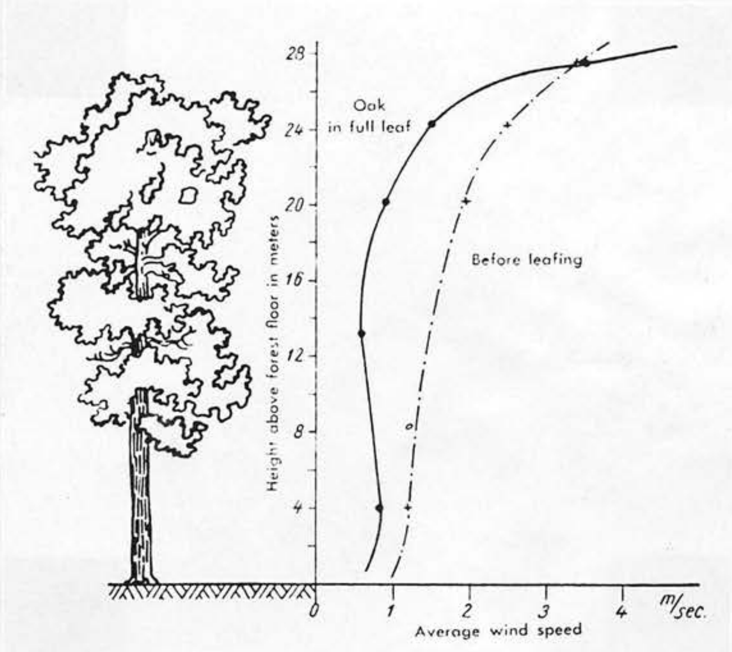


Fig. 3. Influence of foliage on distribution of wind speed in an oak grove with beech understorey.
(after Geiger and Amann).

stand in Germany. Interspersed amongst the oak were 40 to 50 year old beech in the pole stage. Reduction in wind speed is greater when the trees are in full leaf. In this same stand Geiger measured the number of calm hours within the stand before and after leafing - calm hours being defined as those with a wind speed of less than 0.7

metres per second (about $1\frac{1}{2}$ m.p.h.). The results are given in tabular form below.

Height above forest floor		Position of anemometer	Number of calm hours.	
			Before leafing	After leafing
m.	ft.		%	%
27	$88\frac{1}{2}$	Above the crown	0	10
24	$78\frac{3}{4}$	In the crown	8	33
20	$65\frac{1}{2}$	Lower edge of crown	35	86
4	13	Above the forest floor	67	98

There is a significant difference between reduction in wind speed within a forest and in the lee of a shelterbelt. While the efficiency of a shelterbelt is static, that of a forest generally increases as the wind in the open increases (Kittredge, 1948; Geiger, 1957). This effect can be seen quite clearly in figure 2, but the distances involved between the windward edge of the forest and the points of measurement are not mentioned. Caborn (1957) quotes measurements by Nägeli made in a coniferous plantation with a width, near the measurement line, of 600 metres (654 yards). Figure 4 shows the reduction in wind velocity inside this forest complex. These measurements show that a distance of approximately 11 times the height of the trees is required to reduce the wind velocity to a minimum within the forest, which amounts in this case to about half the width of the forest. This implies that the wider the forest, the greater will be the area of minimal wind velocity. Comparison with a shelterbelt of similar density, but only 20 metres (1 chain) wide,

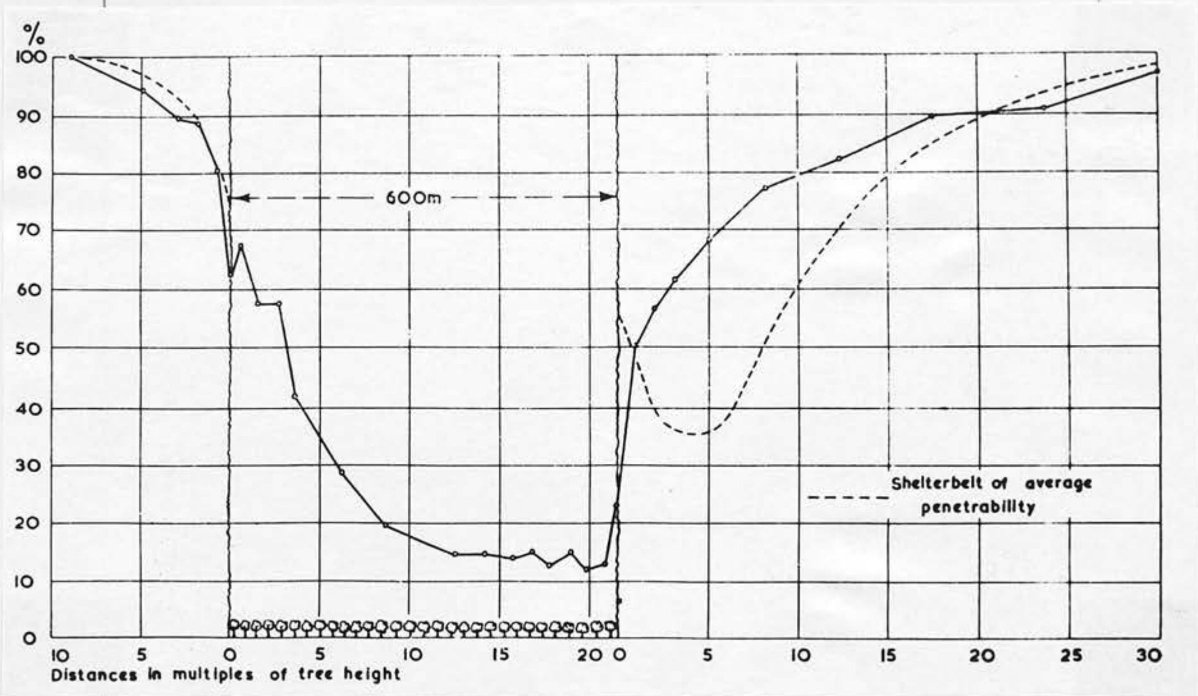


Fig. 4. Relative wind velocities in the vicinity of a large forest complex.

(after Nägeli; Caborn, 1957)

shows that within the shelterbelt wind velocity remains at least 33% above that in the forest.

6. Precipitation

(i) Rain. It is generally agreed that the amount of rain reaching the soil within a forest is less than that outside it. Conifers are more efficient at intercepting and retaining rain in their foliage as the needles act like "combs" to trap the water (Geiger, 1957), whereas with hardwoods the drops coalesce on the leaves and fall to the ground. But this efficiency of interception varies with the intensity of the rain shower as is shown by Ovington (1954) and Geiger (1957). With a light shower (up to 5 mm.), the rainfall is trapped in the tree crowns and evaporated back into the atmosphere. As soon as the precipitation gets heavier and the crowns become thoroughly wet, the rain penetrates to the forest floor either in drops or as stem flow, running down the trunks. Ovington (1954) states that not only do conifers retain five times more water than hardwoods in their canopies when precipitation is light but that more than 50% of precipitation penetrates a hardwood canopy even in light showers. These statements are confirmed by Geiger. Figure 5 shows the

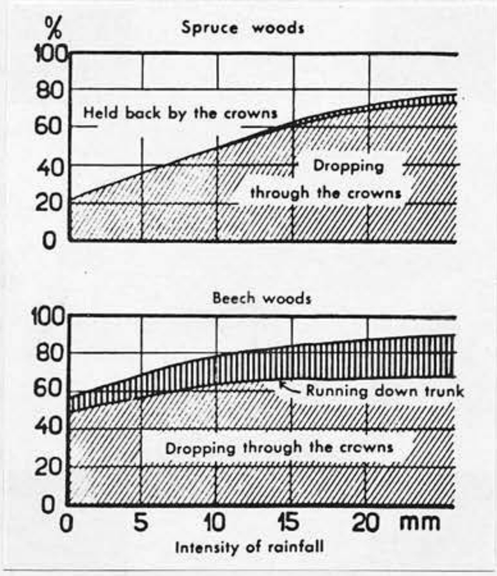


Fig. 5.

Distribution of rain in conifer and hardwood forests.

(after Hoppe; Geiger, 1957)

amount of rain reaching the forest floor under a 60 year old spruce stand and an 88 year old beech stand by dropping through the canopy and by stem flow. Similar graphs were obtained by Ovington (1954) for a variety of hardwoods and conifers. Kittredge (1948) mentions that interception losses also vary with crown density; well-stocked stands intercepting more than under-stocked ones. He states that stands at ages between the closing of the canopy and culmination of the current annual increment intercept more rainfall than those younger or older than this and the following figures of Toumey and Korstian (1947), compiled from Swiss observations in beech stands of various ages, support this.

Proportion of Rainfall -	Age of Stand			
	20 yrs	50 yrs	60 yrs	90 yrs
	%	%	%	%
Reaching ground	98	73	77	83
Retained in Canopy	2	27	23	17

Both Kittredge and Geiger show that the rainfall which drops through a tree canopy is unevenly distributed, being least near the trunk and increasing towards the periphery of the tree.

Madgwick and Ovington (1959) have found that in south-east England the rainfall beneath forest canopies normally contains a higher percentage of plant nutrients than precipitation falling on open ground, as shown in the following table.

	Open Plots		Forest Plots	
	Max.	Min.	Max.	Min.
Na	8.2	0.3	110.1	0.6
K	3.5	0.05	42.8	0.2
Ca	9.8	0.2	128.8	1.0
Mg	0.9	0.5	12.5	0.5
P	0.5	0.05	1.0	0.05

All figures in parts per million

The weight of the chemical contents in rainwater passing through the canopy is broadly similar for all species but differences arise between deciduous and non-deciduous species, depending on the season of the year.

During the leaf-bearing period of deciduous trees the nutrient content of rainwater under such species is higher than under evergreens, while in winter the reverse is true. Madgwick and Ovington have also found that on the same site the amount of nutrients contained in the rainwater of the forest plots is, with the exception of phosphorus, broadly equivalent to or greater than the permanent annual incorporation of nutrients in the tree crops.

(ii) Snow. Snow is more successful than rain in reaching the forest floor because after accumulating in the canopy it breaks away either by its weight or by being blown from the branches.

The distribution of snow accumulation within a stand is that of a minimum directly under the crowns, due to interception, and a maximum in openings, due to reduced wind velocity (Kittredge, 1948), and the general pattern is one of decreased accumulation on the forest floor as the tree canopy increases in density. Thus Kittredge says that there is likely to be a net gain in accumulation in old forests of moderate to low density as well as in young stands before canopy closure, and a net loss in evenly spaced pole forests at ages of maximum crown density and interception.

The rate of melting of snow is decreased by a forest cover and the date of disappearance can be retarded, according to Kittredge, by as much as six weeks under conifers.

(iii) Fog Precipitation. Both Kittredge (1948) and

Geiger (1957) mention the phenomenon of "fog precipitation". This results from the interception of small drops of atmospheric moisture by the surfaces of twigs, leaves and needles of the forest. In time the droplets coalesce and fall to the ground. Fog precipitation is considered to be a forest margin effect and decreases towards the interior of stands. It will, however, only be of importance in those areas where fog, mist and stratus cloud are prevalent.

CHAPTER 4

THE VALUE OF SHELTER TO LIVESTOCK

Cattle and sheep are homeotherms, maintaining a more or less constant body temperature irrespective of their environment. Nevertheless, environmental conditions can impose great stresses on an animal endeavouring to maintain homeostatic equilibrium and Blaxter (1958) recognises two kinds; direct stresses, resulting from temperature, solar radiation, humidity, rainfall and wind velocity, and indirect stresses, comprising those which affect the supply and availability of food. It is the latter which Blaxter considers to be more important in limiting livestock production in temperate climates. He quotes as an example of indirect stress the drop in milk yields of cattle associated with summer droughts and high air temperatures, with a consequent reduction in pasture growth. He argues that it is unlikely to be a result of direct climatic stress as experiments have shown that milk production in cows does not decline until temperatures of 82°F have been reached. As day temperatures, even in the south of England, are rarely above 85°F for long, and in view of the fact that cows have a large heat capacity, it appears that the reduced supply of herbage is the major cause for the drop in milk yields. Similarly, Blaxter maintains that the lower winter milk yields of cattle reflect the indirect stress of climate affecting food supply. Also Munro (1961) states that cold east winds in spring are very damaging as they dry up the pasture and cause milk yields of ewes to fall, resulting in a check in lamb growth. Blaxter considers an extension of the grazing season to be fundamental in alleviating the indirect stress factor in farm animals. The value of woodland shelter in this connection lies in the much-observed effect of prolonging the growing season of grass, though to what extent and under what conditions of climate and tree vegetation does not appear to be recorded. But it was shown in Chapter 3 that climatic conditions within a woodland are more equable than in the open. In particular, minimum temperature, which is probably the limiting growth factor other things being equal, is increased, and thus an opportunity exists for extending the grazing season due to the possibility of growth continuing later into the autumn and starting earlier in spring.

As it is unlikely that indirect stresses on farm animals in winter will be removed entirely, it will obviously be beneficial to alleviate as much as possible the direct stresses due to climatic factors. Much work has been done to determine the effects of climatic stress on farm stock, especially by Blaxter, who considers that livestock habitually kept outdoors are not necessarily as resistant to the changeable British climate as is often supposed. It is well known that in healthy, warm-blooded animals, heat production and heat loss must balance, the equilibrium being affected by either increased heat production or reduced heat loss. Heat losses in animals occur by convection, conduction and radiation. Convective heat loss depends on the temperature gradient between the air and the surface of the animal. (Blaxter, 1961). It increases, according to Blaxter, in proportion to the square root of the wind speed and Lee (1958) points out that this effect is therefore particularly marked at low speeds, becoming less noticeable at higher speeds. Tree shelter is likely to reduce convective heat loss in winter as the minimum temperature of the trunk space is usually higher than in the open and consequently the temperature gradient between the air and the animal's body is decreased. Lee (1958) says that in many ways shelter can be regarded simply as an extra layer of clothes, separated from the pre-existing layers by a space in which air movement can vary over a wide range. The lower wind velocities within a stand would tend to restrict convective heat loss because the insulation of hair or fleece is more efficient when the fibres are undisturbed, thereby confining a greater depth of still air near the body.

Conductive heat loss will depend on the thermal conductivity of the contacting surfaces (Findlay and Beakley, 1955). Armstrong <u>et al</u>. (1959) mention that considerable heat loss can occur while an animal is lying down and Michael (1960) discusses the situation when snow is on the ground. He points out that a snow surface is never above freezing point and that on clear nights its temperature is reduced even more through radiational heat loss with the result that by morning a sheep can often be frozen to the ground. With the longer resting periods required for in-lamb ewes, especially those with multiple pregnancy, the stress imposed by such climatic conditions is high. He mentions that conditions are ameliorated within a woodland. It has been previously indicated that surface soil temperatures in a stand are usually higher than those outside it during the autumn and winter. In cold, frosty weather the advantage of such a situation is again to reduce conductive heat loss while an animal is resting and this will be enhanced by the fact that the thermal conductivity of forest litter is lower than any mineral soil. Wet soil is a better conductor of heat than dry soil, a fact probably accounting for the statement by Wannop (1947) that out-wintered cattle must have a dry resting place if they are to do well, and this can usually be found, he says, where there are trees and slopes.

Blaxter (1961) states that heat losses due to long-wave radiation are determined by the surface temperature of the animal and the surfaces which surround it, that is the ground and sky if outdoors, and he mentions that while ground surface temperature is very close to air temperature, the radiant temperature of the sky can be very much lower than air temperature, by as much as 10°C (18°F) in clear, dry weather, causing high radiational heat loss. Shelter, however, interferes with radiation exchange (Lee, 1958) and this can be of benefit to livestock, especially during the night, by reducing the temperature gradients between the surfaces of the animal, forest floor and tree canopy, thereby cutting down radiational heat losses.

Heat production must now be considered. Findlay and Beakley (1955) have said that in cold conditions farm animals need to obtain and conserve heat. Heat production is achieved by eating more, shivering, or if food is insufficient, by using body reserves. But since an animal's natural winter food supply is already limited, it is unlikely that a significant increase in food consumption would be possible without man's intervention, leaving the alternative method of using body reserves, of which shivering is a part. Blaxter (1961) explains that the source of energy for this heat production is from body fat, as no increase in the breakdown of body protein occurs. But if an animal is growing, and one must realise that this applies to the foetus, there is a decline in the amount of protein laid down, as the deposition of protein in growth involves energy expenditure which is secondary to that used to maintain life under adverse conditions. Thus excessive cold stimulates increased heat production which in the absence of an adequate food supply leads to low productivity. Many authorities have indicated the value of tree shelter in alleviating climatic stress as this decreases the amount of energy required to keep an animal warm and thus there is less demand on its body reserves.

Heat conservation is dependent on the insulating effect of an animal's coat. Blaxter (1961) has shown that the insulating value of a sheep's fleece is 25 to 30% greater than that of the cattle coat, which would explain one of the conclusions from a survey carried out by Munro (1961) that cattle have a slightly greater requirement for shelter than sheep. But in both, wind decreases insulation by reducing the depth of still air confined near the body. However, wind velocity is reduced in a woodland and the effect of an animal taking shelter in it would be to increase the efficiency of its insulating layer. Rain and snow can also increase the rate of heat loss. The efficiency of hardwood shelter against both forms of precipitation appears to be low but with conifers somewhat higher. Cowan (1858) observed that shelter prevented sheep from becoming "shelled" during snowstorms.

Michael (1960) records the advantages of shelter in preventing animal disorders. He shows that during the hard winter of 1955 there were 0.7% of recorded cases of pregnancy toxaemia in sheep that had access to woodland shelter while this figure rose to 4.7% for those without access to shelter. Michael stresses that other factors of flock management are involved but shows an interesting comparison within a flock, in which part obtained access to woods while the remainder did not. No cases of pregnancy toxaemia were recorded amongst the former group but 5% occurred in the latter. The same authority also mentions that lambing sickness (hypocalcaemic tetany) is influenced by exposure, and cites the results of a field trial carried out in 1950. In ewes having the benefit of natural shelter there were only 6% of recorded cases of this disorder compared with 26% in a contiguous flock on exposed ground.

Nichols (1955) enumerates several advantages of shelter. Stock losses and checks to growth are reduced, larger numbers of better quality animals are raised, leading to the production of heavier and better quality stock for market. In addition, a change of enterprise towards more cattle and larger framed, more fertile sheep breeds may be possible.

These advantages are demonstrated from the practical experience of Landale (1961), who compares conditions on a farm, at an average height of 850 feet above sea level in the Lammermuir Hills, in 1896, when there was little tree shelter, and in 1960, when there was a considerable amount of shelter from shelterbelts. In 1896 there were no more than 24 head of cattle whereas in 1960 there were 181, all of which were wintered on the farm. Previously ewe hoggs were wintered away but now it is possible to winter them on the farm. Hill Cheviots were bred on the low ground in 1896 but now this flock is the much heavier North Country Cheviot, the changeover being achieved without any reduction in numbers. After adjusting 1896 hill sheep prices to those prevailing in 1960, Landale records a rise in the value of his stock of £19,200, an increase of £300 a year since 1896. He admits that this great increase in productivity is due largely to improved farming techniques but he considers that from one quarter to one third is a direct result of shelter.

Although the physiological and microclimatic benefits of shelter for stock have been established independently by many workers, present work does not appear to extend to determining the magnitude of these effects under natural conditions.

CHAPTER 5

FACTORS AFFECTING FOREST MANAGEMENT FOR SHELTER AND GRAZING

1. Ownership. This can be of considerable importance where multiple land-use is concerned because landowners tend to have a personal bias towards one aspect at the expense of others, and where ownership is absolute there is little that can be done, when persuasion has failed, to prevent misuse of resources. Sampson (1952) records such a situation in America. After the formation of the Forest Service, much research was carried out to determine the best ways of using forested range land for combined grazing and timber production, which had previously been greatly overstocked with cattle. The results of the work were applied to federally-owned forests and many of the range land abuses have been corrected. Federal and State laws now control grazing on their forested range land. However, on private land the Forest Service has no legal powers to prevent overgrazing and can act only in an advisory capacity. Sampson (1952) mentions that progress in adopting better management and improvements in range condition have been slow. Stoddart and Smith (1943) note that multiple ownership is another obstacle to efficient control of American range land.

Parallels can be found in Scotland. Robertson (1958) writes that the common grazings in the Scottish Highlands are now regulated, as to number and kind of stock, by grazings committees. This was brought about mainly as a result of the inefficiency of uncontrolled grazing, leading to over-grazing and deterioration of land and stock. However, he notes that the Clerks of grazings committees have no executive or disciplinary powers and stocking rules have often been neglected with resultant over-grazing. Similar difficulties exist on common land even where stinting is in operation, and it seems that legal powers will be necessary before this problem can be solved (Rep. Roy. Comm. on Common Land, 1955-58). It is reported by Eskeland (1955) that in Norway common forests and rough land, over which farmers have grazing and timber rights, are being abolished as a system of reallocation of land proceeds.

As far as improvements to grass- and woodlands are concerned, Rieben (1957) considers that the main responsibility lies with the owner but that the tenant should co-operate by providing labour and intensifying the exploitation of his land where this is necessary.

2. Use and type of woodland. The requirements from a woodland for out-wintering purposes will partly determine the spatial distribution of trees over the ground. Where winter climate is generally not severe, and the provision of shelter secondary to that of forage, the woodland/grazing ratio may be small and the trees may be scattered over the grazing area. Such a situation is described by MacLeod (1960) on an area in Argyll, where oak scrub, mainly of coppice origin, is being thinned out by girdling the oak to leave a very sparse covering of trees over most of the ground. The present low quality pasture is then improved by fertilising and surface seeding. Blocks of woodland

have also been left on knolls and steeper ground due to the difficulty of getting machinery on to these areas. The magnitude of the various shelter effects provided by the remaining tree cover is a matter of opinion, for little work has been done on the microclimatic conditions in open woodlands. But Nägeli (1961) has attempted to assess the reduction in wind velocity by scattered trees and groups of trees on the wooded-pastures of the Swiss Jura, which gives some indication of the degree of wind reduction that might occur over open woodlands. In the first experimental area the main tree species was spruce, 20 metres high (about 66 feet) with branches almost to ground level, and some silver fir, beech and sycamore. These trees were grouped in more or less pronounced belts across the area from south-east to northwest, and at right angles to the prevailing winds - southwest and northeast. Wind measurements were taken in all cases at 1 metre (3 feet) above ground level. In this area Nägeli found that both prevailing winds were reduced to 40% of the free wind speed. In the second experimental area the main tree species was also spruce, with branches extending down to ground level. Mountain sycamore and silver fir were also present. The main difference in this area was that the trees were spread out over the pastures much more closely and haphazardly and there was no kind of belt formation. The wind speed was reduced on average to 53% of that in the open. Nägeli points out that the pronounced belt formations reduce the wind more than the scattered trees. But especially in the first experimental area it seems that some of the shelter effect could be due to the configuration of the ground, which was very irregular. It is also important to note that these results are for conifers. It is likely that during the winter, deciduous trees would not be as efficient in reducing wind speed.

Where shelter is the primary objective fully-stocked high forest will probably be of most use for out-wintering stock. Geiger (1957) quotes many examples of multi-storied forests having a greater beneficial effect on micro-climate than single-storied high forest.

It is when shelter and grazing are both desirable that difficulties of management are encountered. The problem is to achieve a suitable ratio of woodland to grazing. François (1953) remarks that coppices are more favourable to grazing than high forests, for the soil receives more light and herbaceous growth is encouraged. Another possibility is to create openings in the stand or have strips lightly stocked with trees alternating with more dense woodland. Geiger cites an experiment by von Wrede in which he compares two such areas in a stand of pine and spruce mixed with a few firs and beeches. A circular opening with a diameter of 13 to 14 metres (14-15 yards) was made, and nearby a 50 to 60 metre wide (54-64 yards) strip was thinned so that 43% of the canopy remained. von Wrede's results showed that temperature fluctuated less in the opening and wind speed 1 metre above ground level was $1\frac{1}{2}$ times greater under the thinned strip, which also had a relative humidity 5 to 7% less than in the opening. This would seem to favour openings in the forest for herbage growth. But openings 14 to 15 yards in diameter would support little forage for stock. Geiger shows how micro-climate is affected by enlarging such openings. It increases insolation by day and outgoing radiation by night, the latter enhanced by the still air in the opening, leading to extremes in ground temperatures and in some places increased frost danger. But as the openings approach the size when they can be called forest clearings, the wind has a greater effect in mixing the cold and warm air layers and reduces the daily temperature range and frost danger. In the transition from a narrow opening to a broad clearing in the forest there is some size at which the climate becomes extreme. Below this critical size it is milder due to reduced radiational absorption and loss and above this size because of the greater mixing of air. The determining factor appears to be the ratio of the diameter of the clearing to the height of the surrounding stand (i.e. D/H ratio, or "index size" of clearing.) Geiger has carried out experiments to determine this critical index size for several climatic factors. Circular cuttings of different sizes were made in a 26 metre (85 feet) mixed pine and beech stand with the following results:

Diameter D, in metres	12	22	24	38	47	87
Index size D/H	0.46	0.85	0.93	1.47	1.82	3.36
Outward radiation (% of that in open)	11	31	33	52	66	87
Rain (% of that in open)	87			105		102
Noon temp. (June, amount warmer than stand)	0.7	1.6	2.0	5.2	5.4	4.1

Geiger concludes that the clearing with the index of 1.5 represents the critical size for the set of factors measured above. Therefore, in order to avoid a climate of extremes, the clearing would need a diameter larger or smaller than 38 metres. In this example the clearing of diameter 47 metres would have an area of 0.45 acres. This is a more practical size as far as grazing is concerned and would also allow the use of the group selection silvicultural system for the tree cover, as 0.4 to 0.5 acres is a reasonable size for a group of regeneration.

3. Effect of trees on vegetation. It is well known that tree cover reduces the growth of vegetation under it. Ovington (1956) quotes Aaltonen as giving the causes as reduced light intensity at ground level and competition from tree roots. Ehrenreich and Crosby (1960) report on an experiment carried out in low grade hardwoods in the Missouri Ozarks in the U.S.A., to determine the effect of tree cover on herbage production. It was found that open areas produced 1,700 lb. of oven-dry herbage per acre whereas dense stands, with 80% or more crown cover, produced only 250 lb. per acre. As the crown cover was reduced from 80 to 50% there was only a small increase in grass production but with successive decreases from 50% crown cover to none there were relatively large increases. In another study in Missouri, Ehrenreich (1960) obtained similar results under pine stands. Several plots were thinned to 110, 90, 70 and 50 sq. ft. basal area per acre and compared with an unthinned control plot with a basal area of 130 sq. ft. per acre. Results showed that the

herbage yield increased 4 to 5 times as the basal area was reduced from 130 to 70 sq. ft. per acre, and that an increase of more than 14 times could be obtained when basal area was reduced to 50 sq. ft. per acre. Timber production was still good in stands thinned to a basal area of 70 sq. ft. per acre. Smith et al. (1958) carried out some work in the Gulf Coastal Plain of South Mississippi, U.S.A., to examine the amount of native forage under various stands and densities of second-growth Longleaf pine. When the study began the trees were 35 years old. Grass yields were measured in three different stand densities. Results showed that in open stands, containing 30 pines per acre of 4 in. diameter at breast height or larger, the average annual yield of grass (air-dry) over a 3 year period was 850 lb./acre. In moderately dense stands, with 225 trees per acre, grass production was 450 lb./acre. Dense stands, of 300 trees per acre, yielded 400 lb./acre of grass annually. These figures indicate that an increase in grass production occurs as tree density is reduced. It was noticed in this experiment that as the trees grew the vegetation tended to become smothered by accumulated litter and in the dense stands much of the forage was untouched for this reason. Further work carried out in the U.S.A. appears to confirm that tree cover reduces forage yields.

It may be possible to alter a thinning régime or final exploitation in order to maintain a supply of forage. Baskett et al. (1958) found that in a typical white oak stand in the Southern Ozarks in the U.S.A., the felling of individual merchantable trees increased the amount of vegetation in the openings around the stumps and the effect was still apparent 9 years later. They therefore recommend a 10 year timber cutting cycle in this forest type as this will provide a continuous supply of forage.

The tree species are also likely to have a great effect on vegetation, those with light canopies allowing the greatest growth. Michie (1885) comments at great length on the merits of European larch as an improver of pasture lands on the Atholl Estates. He considers that after 30 years, when this species has been thinned to 320 trees to the acre, the grazing value of the pasture is worth 8 to 10 times its original value as bare pasture. He also mentions that forage in oak copses reaches a maximum value every 24 years, when the timber is cut down, implying a coppice rotation. Ash is stated to increase the value of grazings 2 to 3 times, Scots pine not at all, while beech and spruce decrease the value. Nisbet (1893) mentions the value of European larch in mountainous country for improving the quality of the grasses, though he says they must be planted far apart. Ash, and pedunculate oak at wide spacing, are also noted as not diminishing the growth of grass. Poncet (1957) describes the virtues of larch in the High Alps of France as ameliorating the sward and increasing its production. He quotes Hess as saying that there is no tree more suitable for pastoral culture, as a strong grass sward develops under its light canopy, the litter decaying easily and not clogging the sward. Fenton (1951) notes the beneficial effect of birch woods in producing good grassland in Scotland and advocates an increased acreage of this species to maintain and/or improve hill grazings. Moreover, he observes that woodlands tend to shade out heather which is superseded by grass, thus providing a valuable early bite for sheep in spring. Semple (1952) also records that shade tends to suppress coarser grasses.

This increase in the value of pastures brought about by the presence of trees and the nutrient content of woodland vegetation are controversial issues. Pearsall (1950) has indicated that trees draw minerals up from deep down in the soil and some of these nutrients are returned in the leaf fall. As the leaf litter decays the herbaceous vegetation can assimilate these elements which would otherwise be beyond the reach of their relatively shallow roots. Experiments by Ovington (1956a) have shown that woodland ground vegetation can contain greater percentages, per unit dry weight, of the various elements than similar vegetation in the open, this being influenced by the weight and composition of the leaf fall. Hardwood leaves have been found to yield greater quantities of Mg, P, K and N than conifers, though the latter contain higher percentages of Na and Mn. Larch is anomalous, behaving in this respect more like a hardwood, for it was found that the needles contained a relatively high percentage of P, which was reflected in the higher P content of both the ground flora and mineral soil. This nutrient cycle is generally of two years duration in hardwoods but with conifers, as they are non-deciduous, it can take at least 6 years (Ovington, 1959). Ovington

(1956b) points out, however, that the greater oven-dry weights of vegetation obtained on open ground more than compensates for the smaller percentage content of the various nutrients. Hawley and Stickel (1959) also quote figures to show reduced herbage production under forest conditions.

Guise (1939) mentions that studies have been made which indicate that the nutrient content of woodland grasses is much lower than in grasses from open pastures. On this same point Hawley and Stickel make the rather ambiguous statement that the quality of forage growing within a forest is not equal to the <u>same amount</u> of forage grown on areas which are not forested. This is at variance with Ovington's results. If the comparison is between woodland forage and that from improved pasture growing in non-forested areas this statement is probably true but there is little evidence to suggest that herbage from woodland, compared with that from a similar vegetation type in the open, is of lower quality. Indeed, François (1953) states that the quality of forage is little influenced by tree density but that palatability varies with the amount of light received. Hawley and Stickel agree that palatability is reduced by shade, due to the smaller sugar and starch content of the grass. However, Tribe (1950) states that the sugar, protein and vitamin contents of plants do not apparently determine their palatability. He quotes several authorities as having found no correlation between nutritive value and palatability of herbage. This, Tribe explains, is due to certain factors, such as pain, fear, discomfort, sex drive and the like, which have a primary influence over an animal and the instinct or drive to select a diet capable of maintaining chemophysiological equilibrium is secondary and subordinate to these factors.

There is clearly a need for further work to clarify these issues.

4. Effect of stock on stand.

(i) Type, density and distribution of stock. Most authorities agree that goats are the most and cattle the least destructive beasts of woody vegetation, with horses and sheep lying somewhere in between, though François (1953) and Hawley and Stickel (1959) note that all domestic animals will browse on trees and shrubs either casually or through lack of more palatable food.

François states that although goats eat both herbaceous and ligneous vegetation they have a preference for the latter. Sampson (1923) says that goats are liable to cause more damage to timber reproduction than other classes of domestic animals because a larger number of timber species are palatable to them, though Stoddart and Smith (1943) record that where good forage is present they are fastidious and graze less destructively than sheep. Nevertheless, Sampson (1952) is of the opinion that goats should be eliminated from areas where regeneration is required.

Horses, being larger and heavier animals than sheep and goats, are capable of doing more damage through trampling on young trees. They are also, according to Fürst (1893), prone to browsing on foliage and young succulent shoots of saplings. Stoddart and Smith point out that horses have both upper and lower incisors and tend to bite cleanly rather than tear and rip at forage like cattle. They can therefore crop herbage more closely and are capable of extreme over-grazing.

Sheep, being smaller than horses and cattle, probably cause less damage by trampling on plants. Fürst notes that sheep like gnawing and browsing on woody plants but Stoddart and Smith indicate that they prefer to eat grasses.

Cattle only attack ligneous vegetation when there is a dearth of more palatable forage (Fürst; Sampson; Francois; Hawley and Stickel). Recent work in America seems to indicate that most cattle damage to tree growth is not due to browsing.

The density of stock in a particular forest is, according to François, a most important factor. He explains that under natural conditions the forest and its animal production are in equilibrium but when man takes over the number of wild animals usually diminishes. In order to restore the balance François suggests restocking with domestic animals provided they are controlled by man, just as the wild animals would have been controlled by predators. He also considers that where wild and domestic animals are to use the same area it is necessary first to decide how many of the former are to be conserved before determining the stocking of the latter. Finally, the density of domestic stock must be governed by the available forage resources, and since these vary from year to year, the stocking should vary accordingly. All authorities agree that careful control of livestock numbers is imperative for successful forest grazing.

Correct stocking must be combined with even distribution of stock over an area. If this is not done animals congregate on certain portions of the forest and can cause severe damage by over-grazing, while other areas remain untouched (Hawley and Stickel). François[5] recognises distribution of stock in both space and time. Distribution in space involves varying the number of head of stock over different parts of the forest and this will be controlled over the years (distribution in time) by the various silvicultural operations, as these have a considerable influence on the quantities of forage available. This distribution of stock in space and time is the chief task of forest grazing management (François[5]).

(ii) Available forage, tree species and season of use. Sampson (1952) states that where forage is limited or unsuitable for the animals being grazed, browsing is likely to be serious. Thus during the late spring, summer and early autumn, when forage is plentiful and palatable, damage from browsing will be at a minimum. During late autumn, winter and early spring, however, herbage is scarce and relatively unpalatable and browsing damage is likely to be at a maximum, especially during periods of snow when there is probably little herbaceous vegetation above the snow surface. Hawley and Stickel note that animals prefer to browse on hardwoods but that recovery from injury is better than in conifers. There is also a wide difference in susceptibility to grazing damage between the various tree species.

(iii) Damage to trees.

(a) Regeneration. Hawley and Stickel note the following general effects of grazing on regeneration: an unfavourable seedbed can be created through soil compaction; seedlings and young growth may be severely browsed as well as being broken, bent or trampled on by animals; roots may be exposed or barked and sometimes bark is gnawed and peeled from seedlings. Benefits from grazing can occur by the creation of favourable conditions for regeneration through disturbing and exposing the mineral soil as well as by the treading in of seeds. It is said that reduction of weed growth associated with grazing is a considerable help in the establishment of seedlings in some cases.

Stoddart and Smith mention that sheep probably cause less damage to regeneration by trampling than do cattle and horses due to their smaller size. Also the sheep tends to nibble when eating and thus causes less physical injury to plants than do cattle and horses. These authors also record that sheep prefer to eat grasses where they are available. But Maki and Mann (1951) have shown that they are capable of considerable damage to conifer regeneration. They studied for two years the effects of sheep grazing on longleaf pine seedlings on a 1,300 acre pasture in Mississippi, U.S.A., where the sheep stocking was 1 to 12 acres. The observations and measurements were carried out on seedlings between 2in. and 48 in. in height, on 22 pairs of

1/10 acre plots, one of each pair being fenced and the other open for yearlong grazing. The average stocking of seedlings was 1,486 per acre on the fenced plots and 1,442 per acre on the grazed ones. Their results show that during two years of continuous grazing 86% of sample seedlings were browsed by the sheep and 50% of seedlings lost terminal buds 2 or more times. Damage was highest on seedlings less than 24 in. high but enough choice seedlings and saplings between 24 and 48 in. were browsed to warrant protection until a height of at least 4 feet has been attained. Mortality directly attributable to sheep grazing was not heavy but 15% of browsed seedlings were so badly deformed that they will not make crop trees. Height growth averaged nearly 26% less on the grazed plots. Browsing was found to be seasonal, heaviest damage occurring from October to March, but enough buds were eaten during the summer to suggest yearlong protection may be desirable until the seedlings are about 4 feet high. As a result of experiments carried out in Japan by Kaminaga <u>et al</u>. (1956) on larch-planted land, it is recommended that sheep be excluded from larch plantations until the seedlings are 1.2 metres high (4 feet) to avoid damage to the terminal shoots. Sheep are also destructive in hardwood stands. Sampson (1923) records that in the open aspen stands of America sheep eat the leaves and twigs of this species in spite of there being abundant palatable forage. As these stands are usually clear-felled and regeneration obtained from coppice shoots it has been found that sheep must be excluded from such areas until a height of 45 in. has been attained by the young growth, which means protection for about 3 years after clear-felling. Sampson (1952) mentions that moderate grazing by sheep is not destructive to Douglas fir and associated tree species in the northwest of America.

Smith et al. (1958) in grazing studies in longleaf pine forests of south Mississippi note that grazing damage to pine reproduction is negligible under light to moderate cattle grazing except in areas where concentration of stock was inevitable. However, protection was necessary for yellow poplar to prevent serious browsing.

Stickel and Hawley (1924) have observed the effect of cattle and horses on pine plantations (red and white pine) in America. They classified tree injuries according to the possible future reduction in density of tree stocking. Thus slight injury included pulling and biting of needles, rubbing against bark and breakage of lower branches. Moderate injury comprised scraping bark at the base of trees and bending them over, while browsing of leaders and upper branches, severe breakage of upper branches, breakage of trees at base and death caused by grazing constituted severe injury. It was assumed that only the latter type of injury would lead to reduced stocking. Eight plantations, lettered A - H, were kept under observation. The spacing between plants in all cases was 6 feet by 6 feet. The results are tabulated below.

Plantation	Area ac.	Age yrs	Av. ht. feet	Tree stocking	Type of animals	Forage	Remarks on Damage
A	9.2	7	5	Complete	7 cattle	Good	63% slight damage (SL) 11% moderate " (M) 26% severe " (SV) all concentrated in an area of 0.1 acre round entrance to stand and near salting trough.
B	13.3	7	$4\frac{1}{2}$ - 5	Good	7 cattle 3 horses	Good	Damage along fence lines; 0.2 acres of which 31% SL, 17% M, 52% SV. Also damage along trails through stand; 0.4 acres of which 62% SL, 32% M and 6% SV.
C	16.7	5	4	Excellent	7 cattle 3 horses	Good	Damage negligible. No area of conc. injury due to absence of fences, gateways, etc.
D	15.4	3	4	-	6 - 8 cattle 2 horses	-	Damage conc. on 0.25 acres along a fence at one end of which is a gateway. In the damaged area 2% SL, 55% M and 43% SV.
E	2.6	6	6	Good	2 horses	Good	Damage evenly distributed over .04 acres of which 18% SL, 64% M, 18% SV.
F	19.4	10	-	-	1 cow 1 horse	None	No forage as stand has closed canopy. Doubtful if any reduction in stocking has occurred.
G	32.3	11	-	Good	Cattle	None	Plantation has closed canopy. No reduction in stocking due to grazing injury.
H	-	0	-	-	Cattle	-	A few weeks after planting some seedlings trampled near entrance to plantation.

Stickel and Hawley point out that severe damage was limited to zones along paths, fences, near watering places and gates. Where there is no concentration of stock or obstruction to movement, trees from 3 feet and upwards in height are safe from grazing injury. Several times cattle were found lying down in the plantations where the pines were 3 feet or less in height but in no case were the stock lying on or against the trees. It was also found that greater injury occurred during the winter. Sampson (1952) states that cattle grazing in pine forests is seldom injurious to regeneration except when forage is limited, the critical periods being winter and spring. Cattle grazing in hardwood forest is generally destructive though Sampson (1923, 1952) notes that whereas sheep destroy aspen coppice after clear-felling cattle do not, and it is recommended that cattle replace sheep on such areas for 3 years after logging. In England, McCavish (1954) noticed that cattle grazing amongst spruces which were in check did no damage to the trees, the stocking being 1 beast to $5\frac{1}{2}$ acres.

Horses are said to be more destructive than cattle, due to their biting habits (Stickel and Hawley) and they should never be grazed in young plantations during winter.

(b) Older stands. There does not appear to be any record of sheep causing direct physical injury to stands once they are past the regeneration stage.

However, young trees need a greater length of time to outgrow the danger of browsing from cattle. Once this stage has been reached Hawley and Stickel (1959) mention that they are free from serious direct injury. The main damage, apart from soil compaction, is caused by trampling and barking exposed roots and the rubbing of heads and horns against tree trunks, the latter also recorded by Edlin and Nimmo (1956). Guise (1939) notes that cattle strip bark from some trees. Fürst (1893) states that young cattle do more damage than old beasts because even when there is plenty of grass they nibble and gnaw woody growth, partly out of mischief and excess spirits and partly to assist teething.

Fürst notes that horses are fond of foliage and will strip trees for a considerable height. Because they are heavy animals and usually iron-shod, their hooves damage superficial tree roots. Edlin and Nimmo record the barking of trees by horses and suggest this is due to hunger or boredom, possibly both. If barking extends completely round the tree, death will occur. Trees noted by these authors as susceptible to barking are elm, sycamore and lime, with oak and conifers suffering much less.

(iv) Damage to soil. One of the hazards of forest grazing is its effect on the soil because the damage cannot easily be detected. The effects may take some time to show up with the result that grazing may continue long after serious damage has occurred.

American workers have been particularly active in determining the quantitative effects of grazing in woodlands. Chandler (1940) carried out experiments in 18 grazed, and an equal number of ungrazed, farm woodlands in Central New York. The sites were selected so that a grazed and ungrazed area could be studied on the same soil type and in no case were the compared areas more than half-a-mile apart. The ungrazed woodland consisted of fully-stocked, second-growth hardwood stands, of which the dominant trees were more than 60 years old. The soil had never been cultivated or pastured. The stands on the grazed areas were similar in species, composition and age but no regeneration or young trees were present. The original humus layer had largely disappeared and grass was essentially the only ground vegetation. The following measurements are the means from the 18 sample areas.

	pH	Organic matter %	Vol. wt.	Moisture equiv. %	Moisture content at sampling time. % oven-dry weight
Grazed	5.69	6.4	1.15	32.0	10.6
Ungrazed	5.67	8.5	0.92	36.8	14.4

	Air temp. °C	Soil Temp. °C	Light intensity. %age of full sunlight	Relative humidity %
Grazed	27.1	23.6	21.0	53.6
Ungrazed	25.0	20.1	3.03	65.7

Chandler comments that there is no important difference in pH between the two types. The lower organic matter content of the grazed areas is due to several causes: a lack of understorey and hence less leaves in the litter; reduced crown density and thus less leaves falling on a given area; greater wind velocity due to lack of understorey and therefore a tendency for the litter to blow out of the grazed area, or at least into depressions. It was found that the soils on the grazed area had a lower percentage of soil aggregates larger than 1 mm. in diameter and thus pore space would be reduced, accounting for the increased volume weight. Chandler also suggest that the lower organic matter content is a contributory factor to the higher volume weight as it might cause an increase in the actual specific gravity of the soil. The lower soil moisture content of the grazed woodlands is accounted for by the increased sunlight and wind velocity which produce high rates of transpiration and evaporation from the soil surface and these differences extend well into the subsoil. It is pointed out that on the sloping areas in these experiments, differences may be partially due to a relative increase in runoff. In all ungrazed areas in which the humus was a coarse mull, intense earthworm activity was noted. In the grazed woodlands, observations indicated decreased earthworm activity, and in certain cases it was difficult to find any earthworm castings. Chandlers suggests this may be due to the small number of large aggregates which leads to warmer and drier soils, creating a less favourable environment for worms. The lack of understorey accounts for the increased light intensity in the grazed woodlands while the poor crown densities in these areas are due to less vigorous tree growth and failure to close canopy, after the removal of a few trees, due to a lack of regeneration. Chandler mentions that the extra sunlight reaching the forest floor in the grazed areas was undoubtedly the principal cause of increased soil and air temperatures and the high relative humidity on the ungrazed sites was due to moister soils, greater leaf area for transpiration and decreased wind movement.

Later work by Steinbrenner (1951) carried out in farm woodlands in southern Wisconsin confirms Chandler's results for he found that soils of grazed woodlands had a lower total percentage pore space, macroscopic pore space and microscopic pore space. In addition he found that in ungrazed woodlands the air permeability of the soil could be as much as 8 times higher than in grazed woodlands and that the water permeability and number of water stable aggregates was also higher in ungrazed woodlands. Read (1957) states that trampling affects soil porosity and shows the comparison between protected and unprotected shelterbelts in South Dakota (average readings of 3 belts of each kind), on a silty clay loam soil.

	Bulk density gms./cc.	Total pore space	Large pore space
Unprotected	1.22	51.7%	7.6%
Protected	1.01	57.3%	14.1%

It is reported by Mustafaev (1957) that heavy grazing in shelterbelts impairs crumb and pore structure, which results in decreased infiltration rates. Stoeckler (1959) also records a drastic reduction in infiltration rates due to trampling by livestock. From experiments in Southwestern Wisconsin, he found that grazing reduced the rate of infiltration of soil in oak woods from 7.46 to 0.05 in./hour and in Scots pine stands from 11.02 to 1.23 in./hour.

Edmond (1958) points out that many farmers in the U.K. have recognised the importance of treading damage during the winter when the soils are wet and growth is slow. It appears that treading reduces the vigour of a sward and that increased intensity of treading causes progressively greater reductions in vigour. After puddling, some restoration of soil structure is essential for plant growth. He also records reduced worm population and gleying of the top $1\frac{1}{2}$ in. of soil due to treading.

All these findings are corroborated by Lull (1959). His figures for pressure exerted by various animals on the soil are: horses 29-57 lb./sq. in., cattle 23.9 lb./sq. in. and sheep 9.2 lb./sq. in. These pressures are for static loads only. During movement the body weight is distributed over a smaller area and sometimes the entire weight of an animal is on one foot, in which case these figures may be exceeded by four times. Compaction by trampling, according to Lull, affects the upper 6 inches of soil and exerts pressures equivalent at least to those of heavy tractors. He quotes Keen and Cashen as having found that sheep compacted light sandy soil to a depth of 10 cms., the greatest compaction being at a depth of 3 to 4 cms. These results were obtained by measuring the resistance of the soil to the passage of a rod forced through it. Alderfer and Robinson are cited as having found compaction limited mostly to the surface 1 inch layer. On a variety of pasture sites on clay loam and sandy loam soils in Pennsylvania, U.S.A., bulk densities in this layer ranged from 1.54 to 1.91 for heavily grazed sites and from 1.09 to 1.51 for ungrazed and lightly grazed areas. Non-capillary porosity for the two conditions ranged from 3 to 10% and 15 to 33% respectively. These authors later found a platy structure in the 1 to 5 inch depth that did not affect bulk density but would probably affect infiltration and runoff. In the Allegheny River watershed, average bulk densities in the A_1 horizon of moderately grazed and ungrazed woodlands were found to be 0.92 and 0.51 respectively, and 1.07 and 1.01 respectively in the lower A horizon. Associated non-capillary porosities were 12.6% and 23.4% for the A_1 and 13.7% and 14.8% for the lower A horizon. In Ohio, Lull cites Auten as having found the average weight of 180 samples of air-dried soil, of equal volume taken to a depth of 9.25 inches, to be 15% heavier in grazed woodland compared to that in ungrazed stands. In western North Carolina soil compaction in grazed woodlands, as measured by the difference in total porosity of grazed and ungrazed soil samples, was found to vary with use by forest types. In the most heavily grazed cove-hardwood type, total porosity in the 2 inch depth was reduced by 42%. and in a more lightly grazed oak-hickory type by 15%. In the 2 to 4 inch depth the respective values were 56 and 12%. These changes, Lull mentions, occurred over an 8-year period during which cattle were grazed only during the summer months. There was also a major effect on soil moisture movement, for infiltration in the cove-hardwood type was reduced by 91% and by 67% in the oak-hickory type. At the 2 to 4 inch depth percolation in each type was reduced by 91% and 32% respectively. Total porosity and non-capillary porosity were found to be greater in ungrazed than grazed woodlands in Southern Wisconsin, and the permeability of 2 inch soil cores from ungrazed woods was 3 to 245 times higher than that from grazed areas. Lull states that soils with a wide range of particle size compact to much greater densities than soils of uniform grain size. Trampling most commonly produces hardpans on medium textured soils - loams, sandy loams and silt loams. Soil structure will also determine the degree to which a soil can be compacted, the less dense the soil, the greater the opportunity for compaction. Soils with a good crumb structure have low bulk densities and are highly permeable. Trampling destroys this crumb structure and the interaggregate pore spaces become filled with soil particles leading to reduced permeability. Lull also notes that trampling destroys the crumb structure normally associated with a grass sward. A most important factor affecting soil compaction is the moisture content of the soil, for Lull states that the greatest compaction can be achieved for least effort when soil is at a moisture content slightly less than its plastic limit. This is given as about midway between soil moisture tensions of 0.06 and 15 atmospheres, corresponding roughly to field capacity and wilting point. Organic matter content influences compaction, the higher the content the less the compaction. Forest humus and litter have a cushioning effect which may give a certain amount of protection from compaction. The duration of compaction effects is not known with any certainty but Lull mentions that it depends largely on the stresses created by swelling and shrinking arising from changes in moisture content and temperatures. He quotes an experiment by Garner and Telfair, who buried puddled soil sample cores at various sites and depths. These were examined periodically for changes in structure. It was found that within a year or less rapid structural restoration took place under cultivation, under a grass sward or in the presence of high organic content. Slower changes occurred in cores low in organic matter and in dense woodland sites, due to the forest cover protecting the cores from volume changes arising from fluctuations in moisture and temperature. The overall result of soil compaction and its associated effects on the forest is to reduce the rate of tree growth, as lack of moisture and/or air kills the tree roots. Natural regeneration is also retarded or entirely prevented because of the inability of the radicles of germinating seeds to penetrate the compacted layers of the soil.

It appears that forest grazing also influences the chemical properties of soils. Steinbrenner records that the pH of ungrazed woodland soils in Southern Wisconsin was found to be higher than in similar grazed areas and that the organic matter content of the former soils was also higher. Furthermore, the available P and K was higher in ungrazed areas as well as the replaceable Ca and Mg. Similar results were obtained by Leaf (1958), who analysed the surface 6 inches of soil taken from grazed and ungrazed hardwood stands in Northern and Southern Wisconsin. His figures are shown below.

Sample	pH	Organic matter %	Avail. P lbs/acre	Exch. K lbs/acre	Exch. Ca Me./100 g.	Exch. Mg Me./100 g.
Grazed	5.7	2.2	69	297	5.50	1.85
Ungrazed	5.4	2.1	48	166	5.45	1.73
Grazed	6.5	4.3	64	269	15.70	3.15
Ungrazed	5.7	2.8	71	186	9.05	3.05
Grazed	6.2	2.9	28	287	2.50	2.88
Ungrazed	6.0	2.4	37	179	1.80	1.83
Grazed	6.3	4.4	92	315	4.30	2.39
Ungrazed	5.9	2.1	55	172	1.45	0.56

Although the manurial effect of dung and urine is usually considered beneficial, it may be harmful, especially to conifers where a low pH is more favourable to growth. Russell (1961) indicates that high concentrations of ammonia in the soil can arise in the urine patches of grazing sheep and cattle. He quotes figures by Doak who found that sheep wetted about 45 sq. ins. of pasture per urination, which is equivalent to adding urea at the rate of 700 lb./acre in the urine patch. If the urea is hydrolysed quickly the pH of the soil can be raised from 5.5 to 9.5 in a few hours, causing both a loss of ammonia as gas and an accumulation of nitrite due to this high ammonia concentration. It seems possible that high concentrations of free ammonia in the soil may be toxic to tree roots.

At present the effect of grazing on soil microfauna is an unknown quantity. Haarløv (1960) states that the microarthropods (collembola and mites) are confined predominantly to the litter and humus layers on account of their relatively large size. Under natural conditions the possibility of migration downwards is diminished when passing from the organic layer (A_0H) to the mineral soil (A_1 layer). In periods of drought, therefore, the micro-arthropod population is in danger of dying out, because the majority of species are not capable of withstanding high temperatures and/or low humidities. As grazing animals would tend to break up any litter layer and scatter it about the woodland, it is very likely that the litter will tend to dry out, creating an unfavourable environment for the micro-arthropods. This would result in the larger species dying off while those smaller species which are capable of migrating into the mineral soil would do so. However, it has been shown that the temperature of grazed woodland soils is higher than under natural conditions and the moisture content is lower, both factors creating an unsuitable environment for the mites, which may then migrate still further down into the soil, a feat which would probably be rendered more difficult due to the reduction in pore space by trampling. This may then result in a very low rate of litter decomposition which may partly account for the lower organic matter content of soils in grazed woodlands.

Although there is plenty of evidence to indicate that grazing is harmful to forest soils it must be pointed out that all the results quoted above, with one exception, omit any reference to the time scale involved in producing soil damage. It would be useful to know the duration of grazing as well as the density of livestock per unit area required to bring about the changes observed in the above experiments.

(v) Other damage. Urquhart (1953) and McCavish (1954) mention that cattle in woodlands damage open drains and ditches. McCavish also notes that when stock concentrate on forest rides, any parts that have a tendency to be wet will be puddled and machinery might get bogged down.

Hawley and Stickel (1959) remark that over-grazing is injurious to the health of a forest and renders it more susceptible to attack by insects and fungi. Particularly in hardwood stands, grazing is said to destroy cover for birds and thus indirectly assists in driving them from the forest.

5. Effect of stock on vegetation.

(i) Type of stock. Vegetation can be influenced according to the type of livestock used for grazing. Stapledon and Hanley (1927) record that sheep are moderately selective in their grazing habits, choosing the finest bottom grass and grazing it hard. Grazing with sheep alone is therefore only satisfactory where herbage is short and consists almost entirely of the dwarfer grasses and clovers.

Horses are very fastidious. They over-graze the finest patches of herbage and ignore the coarser and less palatable grasses. This grazing imbalance is further aggravated by the tendency for dunging to be concentrated on the undergrazed parts, which become coarser and coarser, as horses will not graze areas contaminated by their dung (Stapledon and Hanley).

Cattle are not very selective and are better grazers than any other single class of farm stock. Stapledon and

Hanley mention that mixed grazing is the ideal, with the inclusion of cattle in every mixture as horses and sheep graze closely the same type of vegetation and both ignore the coarse grasses.

(ii) Season of use. In perennial grasses, plant nutrients are stored in the roots towards the end of each growing season. These nutrients are used for growth at the beginning of the next growing season before the plant has produced enough leaves to manufacture its own food supply. Therefore if heavy grazing takes place in early spring when the new grass leaves are developing, death of the plant may occur because once the store of food materials for growth is exhausted there is no way of replenishing them. Similarly, heavy grazing towards the end of the growing season prevents the herbage from laying down a sufficient store of nutrients for the following year, resulting in reduced vigour or death (Stoddart and Smith, 1943; Semple, 1952). Hughes and Nicholson (1961) state that continuous early grazing in successive years, especially by sheep, will lead to deterioration of the sward and Stapledon and Hanley (1927) remark that the persistency of all grasses will be adversely affected by early grazing of the same site every year. Therefore to maintain a vigorous and healthy sward the same area should not be grazed early in spring each year and to avoid this Hawley and Stickel (1959) recommend rotational grazing. Likewise heavy grazing in autumn should also be avoided.

(iii) Fire prevention. Leloup (1953) recommends grazing in forests to reduce the fire hazard. But he emphasises that it must not jeopardise the forest and that stock owners must be prepared to support the protection policy, even if it sometimes means the closure of the forest to grazing.

Hawley and Stickel (1959) mention that grazing is distinctly beneficial in reducing the forest fire danger both by removing inflammable vegetation and by assisting in breaking up slash and dead material, thus hastening decay. In fact they state that the beneficial effects of grazing upon fire protection may offset all other injuries to the soil and forest.

However, McCavish (1954) reports that cattle were ineffective in reducing the fire risk in Redesdale Forest, Northumberland. Stock were allowed into stands averaging 16 years old, comprising 80% spruces, with a ground vegetation mainly of Molinia with patches of Calluna throughout. The majority of the tree crop was at the stage when lateral branches were beginning to close canopy yet were not sufficiently advanced to brash. Observations disclosed that the cattle only grazed areas which the trees would allow them to penetrate, such as checked areas. No damage to trees was noticeable. For the most part, however, the stock grazed on forest rides, puddling the wet parts and making them unfit for vehicles.

6. Silvicultural systems

François (1953) states that coppice is more favourable to grazing than high forest because more light reaches ground level to encourage herbaceous growth. Urquhart (1953), however, advocates coppice rotations for a different reason. He observes that in southwest Scotland there are extensive coppices of oak, ash and birch which, if carefully managed on a short rotation, would provide fuel, shelter and some fodder for cattle. Concerning the latter item he remarks that cattle eagerly eat fresh leaves. The use of foliage as fodder may have its place in some parts of Scotland but it does not seem to be widespread at present. In Germany Nehring and Schütte (1950) and Nehring and Schram (1951 a and b) have carried out analyses to determine the composition and fodder value of foliage and twigs and there would appear to be great possibilities for their utilisation.

Fürst (1893) infers that grazing is not practicable where the selection system is in use because there will always be vulnerable young growth and it would be impossible to protect all the areas undergoing regeneration. Hawley and Stickel (1959) also hold this opinion. Furthermore, François (1953) states that grazing is unsuitable in a forest being run on a selection system as the tree cover is comparatively stable and forage resources will remain low. Poncet (1957) mentions that the selection system, usually by groups, has to be used sometimes in the larch forests of the High Alps in France, but that it is not well adapted for forest pastures as regeneration is needed over all compartments and as the seedlings grow slowly in shade they are liable to be browsed for a long time.

The Uniform system of silviculture seems to be very suitable for forest grazing. This system is used wherever possible in the fully-stocked, dense, even-aged high forest of larch in the High Alps. Poncet describes how forestry and grazing on 5,000 hecatres (12,360 acres) of this type of forest in the Inspection of Briançon are combined. The floating periodic block method of forest management is used and the larch is grown on a rotation of 180 years. Between 40 and 120 years selective and progressive thinnings are carried out, with more drastic regeneration fellings taking place between 120 and 180 years. Grazing is permitted for 100 to 120 years on only 2/3 of the area (8,240 acres) at any one time and is confined to those parts of the forest which are undergoing progressive thinnings. This means that grazing takes place in the stands in the 0 to 120 age classes. The remaining 1/3 of the area (4,120 acres), the 120 to 180 age classes undergoing regeneration fellings, is protected from grazing for a period of 60 years and regeneration is therefore practically guaranteed.

Where clear-felling is employed Whyte (1952) mentions that grazing must not be allowed on the felled areas until regeneration is established, but American experience shows that trampling and grazing is often beneficial in helping seedlings to become established.

7. <u>Pasture improvements and grazing régimes</u>

In many cases significant improvements in the quality of grazeable herbage can be obtained by altering the grazing régime alone. Kidd (1957) notes that <u>Molinia</u> vegetation can be converted to a bent/fescue association simply by increasing the grazing intensity, though he mentions the process is hastened by the application of fertilisers. Wilson (1936) records a substantial change in vegetation on Boghall Hill, Midlothian, from a *Nardus* dominant type to an *Agrostis* dominant type by agisting cattle to the hill in summer to supplement the sheep flock. He notes that the change is aided by the application of phosphatic manures.

Ellison (1953) states that in areas where there are reasonable amounts of the better grasses, an increase in productivity can be achieved at fairly low cost by the application of fertilisers. This method is particularly suitable where the soil is shallow or the ground so steep that ploughing and reseeding might fail through lack of consolidation or erosion. Two advantages are claimed for this method of sward improvement: (1) Capital outlay is less than other methods and the necessity for a sudden increase in stock numbers to utilise increased production does not arise; (2) Capital outlay is spread over several years.

A quicker method of improvement is by surface cultivation augmented with fertiliser application. However, Ellison remarks that the main disadvantages are that the original vegetation is not completely killed out and the fertilisers are not very well mixed with the soil to any depth so that penetration is slow. Reversion to the original vegetation may be rapid due to increased growth of weeds by manuring. One particular advantage claimed is that tufted vegetation, such as *Molinia*, can be broken down and a shorter type of sward established. Implements commonly used in this type of cultivation are heavy harrows, discs, cultivators with special tines or some type of rotary hoe. This method can be further supplemented by reseeding. MacLeod (1960) describes pasture improvement in Argyll by manuring and surface seeding only. Results to date have been very satisfactory.

Implicit in the method of improvement by ploughing, fertilising and reseeding is that the land is accessible to machinery and not too wet, and that the soil is fairly deep and free from obstacles to ploughing. Productivity is rapidly and markedly increased but Ellison points out that the problems of this method must be realised before it is undertaken. Often there is a quick reversion to rushes which if not properly controlled by cutting and good grazing management may dominate the area to produce vegetation worse than the original.

Any seeds mixture that is to be used under a tree cover will have to include shade-tolerant grasses. Armstrong (1937) gives a list of species with this characteristic and Davies (1952) mentions in particular two shade-tolerant grasses - cocksfoot and rough-stalked meadow grass. He also points out that clover, a most desirable constituent of all seeds mixtures, demands plenty of light. Stapledon (1936) notes that the common hill pasture grasses are not mineral-efficient whereas many herbs are, and he advocates the establishment of the following mineral-efficient herbs: ribgrass, daisies, dandelions, hawkweeds and buttercups.

In order to maintain or improve herbage production grazing must be regulated carefully and intelligently. All herbage species require rest periods for optimum production (Hughes and Nicholson, 1961) and the best system involves an alternation of grazing and rest periods. Few plants can withstand continuous close grazing, especially by sheep, while close grazing even over short critical periods may be equally harmful to some species. Davies observes that pastures are maintained in better condition if the grazing régime is altered from year to year, as this prevents certain species from becoming dominant and others being eliminated. Semple (1952) quotes the advantage of decreased infestations by internal parasites with a well-regulated grazing régime.

The agronomist recognises four fundamental grazing systems: continuous, rotational, deferred and deferred-rotational grazing. Continuous grazing involves the use of the same pasture area throughout the year. According to Semple it is usually pastures of low carrying capacity that benefit from this system, the main advantage being that the animals graze the various herbage species when they are at their most palatable and nutritious stage.

Rotational grazing consists of dividing an area into two or more parts so that each can be grazed successively or in rotation. The purpose of the system is to confine stock to a certain area so that there is maximum utilisation of forage by close grazing, and minimum wastage through trampling, dunging and selective grazing (Stoddart and Smith, 1943; Semple). Further, it is to prevent continual cropping of the same areas in early spring (Semple; Sampson, 1952), though this latter object is now considered of doubtful value. An interesting variation of this system is mentioned by Stoddart and Smith. It involves a rotation of kind of stock rather than of time, the grazed area being used alternately by sheep and then cattle.

The postponement of grazing until the main forage species have set seed is termed "deferred grazing". The aim is to allow the herbage to reproduce from seed so that new plants can become established, thereby maintaining the vigour of the sward and increasing its area where necessary. Grazing after seed maturity does little damage to the seeds and it is said that the animals have a beneficial effect in scattering and trampling the seeds into the ground (Stoddart and Smith).

Deferred-rotation grazing is a combination of the rotation and deferred systems and tries to combine the advantages of both. It involves the division of an area into several units, which are grazed rotationally, but in addition provision is made for deferred grazing to take place on different units each year (Stoddart and Smith; Sampson; Semple).

Whyte (1952) mentions the use of rotational and deferred grazing systems in the forests of India and also describes a "periodic" grazing system, in which grazing is allowed for a definite period followed by complete closure of the area for another set period. It seems possible to apply the rotational and deferred systems within the periodic one, and the example quoted in Chapter 2, section 2 appears to be a combination of both the periodic and rotational systems.

It is important to note that the pasture improvements and grazing régimes considered above should be directed towards increased winter herbage production, for it is generally agreed that the limiting factor for livestock production on most hill farms is lack of winter keep.

CHAPTER 6

GENERAL CONCLUSIONS ON FOREST GRAZING

In Europe, with the advent of more intensive land use and a general rise in agricultural standards and production, there is a tendency to abandon sylvo-pastoral land use and concentrate forestry and grazing on to separate areas. But in those countries of the world where forest grazing is still a practical necessity, it appears to be most successful when the forester, or some independent body, is in control.

Goats are the most destructive animals of woody growth and many authorities doubt if they should ever be allowed into a forest area. Cattle are the least destructive, with horses and sheep being intermediate between the two. However, it must be realised that winter use of forests by animals is generally recognised to be more harmful than during other seasons of the year.

The quantity and type of forage available each year should determine the density and type of livestock grazed within a forest. Distribution of animals in space and time is essential to avoid concentration in certain areas while other parts of the forest are not used.

It seems inevitable that regeneration will usually have to be protected from all livestock during the winter. The risk of allowing even cattle to graze amongst young growth at this time does not seem to be justifiable by present evidence. However, judicious summer grazing of such areas by cattle appears to be possible without undue damage, and may even be beneficial through reducing weed growth and also the fire hazard. Sheep, on the other hand, should not be permitted to graze where there is vulnerable young growth.

There is little doubt that grazing has many harmful effects on the soil but it is not clear at present what duration of grazing is required to bring about soil damage nor how long these effects last. Yet there is an indication that soil compaction may be slow in disappearing from forest soils, as fluctuations in soil temperature and moisture, which destroy compaction, are considerably reduced within a forest.

Forest grazing will usually result in damage to drains and ditches. Tree roots may be exposed and damaged by trampling, bark gnawed or stripped from trees and trunks damaged by cattle horns.

In order to keep the ill-effects of forest grazing to a minimum, a rotational grazing régime seems desirable where forestry is the dominant enterprise, and where grazing is co-dominant or dominant, probably some form of deferred-rotational use would be more appropriate.

Forest grazing can be beneficial to the forester by reducing the fire hazard, aiding natural regeneration and in certain circumstances may help planted seedlings to become established more quickly by reducing competition from weed growth.

It is apparent that the forester stands to lose much more than he gains from a forest grazing enterprise and it seems reasonable, therefore, that he should have control over all grazing by domestic livestock within a forest area.

PART 2

FIELD STUDIES

CHAPTER 7

APPLICABILITY OF PREVIOUS RESEARCH AND POSSIBLE FUTURE DEVELOPMENTS

At present there is a lack of information from the agriculturist concerning the requirements from tree shelter for out-wintering farm stock. Field studies show that there are differences of opinion as to whether overhead shelter is desirable, i.e. animals being able to get under a tree cover, or whether side shelter, such as can be obtained in the lee of a shelterbelt, is adequate. These requirements will probably vary according to the climatic region, intensity of land use and type of stock involved in the farming enterprise. Nevertheless, more information is necessary on these matters before the problem of out-wintering can be studied profitably in greater detail. This could probably be achieved by an extensive survey among stock-raisers, similar to that carried out by Munro (1961), though covering all the counties of Scotland.

The present dearth of information suggests that the subject of soil compaction should receive considerable attention before condemning or condoning extensive use of forests by livestock.

Microclimatological studies in continental Europe and America indicate the general conditions to be expected within a forest complex yet they are not applicable in a quantitative respect to Scotland as the latter has a more equable climate. It seems desirable, therefore, to repeat a full range of microclimatic experiments in both hardwood and conifer stands over a wide range of elevation in this country, paying particular attention to wind velocity measurements in the trunk space in such woodlands to determine an optimum size of plantation for the maximum area of wind reduction. Also of importance as far as out-wintering is concerned is the effect of different crown densities on the radiational characteristics of hardwood and conifer stands.

The possibility of extending the growing season of grass under the shelter of a tree canopy should be looked into. With this in mind there appears to be an opportunity of developing seeds mixtures containing winter hardy, shade tolerant grasses for use under woodland conditions. Should this prove a practical proposition, further work would be needed to determine the optimum density of tree cover consistent with a dense and vigorous grass sward.

An objective study is required on the effect of a tree cover on the quantity, quality and palatability of grasses. Work to date, both in America and the U.K., has produced inconsistent results on the quality of woodland grasses compared to similar herbage on open land. However, there is evidence enough to indicate that the quantity of grass is reduced with increasing density of tree cover but little information has appeared on the palatability of woodland grasses to livestock during the winter months and factors affecting it, such as contamination of herbage by leaf litter.

The susceptibility of regeneration and young growth to browsing and other damage by livestock has been studied in many countries but the conclusions are generally inapplicable to the present problem as the work has been carried out mainly during the summer season when the likelihood of browsing is low. As there is very little reliable information recorded on this subject in Britain, an attempt should be made to determine the degree of destructiveness to regeneration by the various types of livestock and the seriousness of the damage inflicted, the susceptibility of the various tree species to browsing and other damage, the seasonal variation in browsing, if any, and the age and/or stage of growth at which the various species become invulnerable to serious damage.

Work by Nehring and Schütte (1950) and Nehring and Schram (1951 a and b) on the composition and fodder value of foliage and twigs of hardwoods suggests a suitable source of extra winter keep which could be of considerable value to hill farmers, who generally have a very limited arable acreage on which to produce winter food for cattle. Therefore, it is suggested that a study should be made of the possibility of using the twigs and foliage of hardwoods as fodder, either in the form of silage or in some other condition. Particular attention should be paid to ash, oak, birch and alder, as extensive areas of coppice of these species exist in Scotland which could usefully be exploited for this purpose.

As the protection of regeneration seems essential where forest grazing is practised, fencing of some sort will be inevitable. New methods and materials should be sought which could reduce the cost of this expensive operation. Recently nylon and polythene netting has been produced for fencing purposes and at present trials are in progress in many parts of Scotland to assess its durability. It has obvious advantages over conventional fencing and it is suggested that these materials, and methods of using them, should be tested as soon as possible for effective protection against cattle, horses, sheep, deer, hares and rabbits.

Microclimatic studies in woodlands and the physiology of livestock under laboratory-controlled cold environments have been studied independently of one another up to the present time and there now appears to be a need for correlating these two fields of study to determine the effect of tree shelter on farm animals under natural conditions. There is little practical value, for example, in knowing that on calm, clear nights radiational heat loss from an animal's body will be high, and that woodlands can reduce this heat loss if, for some reason, livestock do not use the shelter at their disposal for alleviating such a stress. Work by Tribe, for instance, has indicated that the primary factors controlling the selection of an animal's diet do not appear to be the nutrient content and palatability of herbage, as would probably be expected, but such things as fear, pain and sex drive. Similar factors may influence the use of tree shelter by livestock. It is realised that experiments under natural conditions are fraught with difficulties due to the large number of uncontrollable factors of the environment but statistical analysis of observations on performance and behaviour, combined with a measurement of liveweight gains, should prove useful in determining the value of woodlands for out-wintering farm stock.

CHAPTER 8

METHOD OF STUDY

Although the shelter effects obtainable from tree cover are well known there is little evidence to suggest that the benefits have been widely exploited in Britain for out-wintering farm stock. The practice occurs in Scotland but the extent is unknown and the effects of livestock on woodlands has received little attention. The object of this study, therefore, has been to review as wide a field as possible relating to this subject in order to determine the uses of woodlands for out-wintering purposes and the problems involved, so that eventually the practice may be integrated with forest management.

Two factors necessarily limited the immediate scope of the work: (1) the general lack of information on the subject of out-wintering; (2) the time factor. A qualitative approach has therefore been adopted at this, the first, stage of the investigation, and no experiments have been initiated, though suggestions have been put forward for future study as a result of this work. It was decided that this stage of the investigation should aim at locating and describing six woodland sites which are being used for out-wintering stock, with a view to prescribing practical methods of woodland management for such areas, paying particular attention to their regeneration.

Concurrent with a review of literature on all aspects of this work, County Agricultural Advisers were contacted for information on the location of blocks of woodland which were being used by livestock during the winter months. Several tours were then carried out to inspect the areas, the primary purpose being to select the six sites for detailed study. However, at the same time much information was obtained on the subject of outwintering farm stock in woodlands and this information forms the body of Part 2 of this report.

Initially the areas for detailed study were to be selected so that each would present as many different aspects as possible of the practice and problems connected with outwintering farm stock in woodlands but inevitably the choice had to be modified by such practical considerations as the proximity of accommodation to site so that the latter was accessible on foot or bicycle, the expectation of continuity of research work once started, the co-operation of the landowner and continued use of the woodland for several years for out-wintering purposes. Many of the sites visited seemed, on first inspection, to be well suited for detailed study but had to be discarded for one or more of the above reasons.

In most cases the writer was working alone which necessarily limited the methods available for the collection of the data in Part 3. Surveying was carried out generally by prismatic compass and pacing. Exceptions were Sites 4 and 5, which were surveyed by chain and compass, though the tree limit on the north of Site 5 had to be estimated because ice and deep snow made conditions on the very steep slopes and gulleys so dangerous during the period of the visit that several attempts to survey it were abandoned.

As the emphasis of management was on the creation of suitable systems to combine forestry and grazing or shelter, it was considered that approximate mensurational data would be sufficient for this work. Accordingly, heights of trees were sometimes estimated, though more often a relascope was used for this, and most other measurements. In Site 6, however, Forestry Commission mensurational data were used.

The Prescriptive sections of Part 3 have been written after consultation with cattlemen and shepherds and incorporates ideas and suggestions from the review of literature and the experience obtained from the tours, always bearing in mind the objects of management of the forestry enterprise. They are intended to indicate the practical methods by which the use of woodlands for out-wintering farm stock may be integrated with good forestry management.

CHAPTER 9

THE USE OF WOODLANDS FOR OUT-WINTERING FARM STOCK

1. Advantages

In Scotland the hill breeds of sheep remain outdoors throughout the year so it is only cattle that are involved in the choice between out- or in-wintering, and the dominant factor determining this decision appears to be an economic one. Buildings of some kind are required for in-wintering and this involves considerable capital outlay which is often not available. Extra winter keep is also necessary for in-wintered beasts because the whole of their food supply must be provided by man for they cannot forage as can out-wintered animals. This winter keep can either be produced on the farm if there is an adequate acreage of arable land or, as more frequently happens, it has to be bought, thereby increasing the cost of the operation still more. The problem of storage space for the extra food supply then has to be solved, and this will probably involve the provision of barns, etc., so that the final cost of in-wintering is very substantial. Therefore out-wintering is frequently a necessity. However, sometimes it is preferred as it is considered that stock are likely to remain more healthy out-of-doors because concentration into a small area, as occurs with in-wintering, increases the risk of disease. Out-wintering often involves less work for farm labour as it dispenses with the need for regular and frequent cleaning out of buildings which would be necessary if cattle were housed, though with the advent of slatted floors this factor will decrease in importance.

The improved microclimate to be found in woodlands should theoretically be of great benefit for out-wintering both sheep and cattle. Reduced climatic stress should result in more efficient food utilisation, for instead of energy being wasted on maintaining homeostatic equilibrium it can be utilised for growth, or at least for the maintenance of bodyweight. This may make it possible to decrease the daily ration of expensive foods, such as hay, silage and concentrates without any ill-effects or even to substitute less hardy but faster-maturing beasts for the traditional hill livestock. The reduction of stresses on pregnant ewes and heifers would probably lead to the production of heavier lambs and calves.

The most widely appreciated benefit of woodlands is the reduction of wind velocity. Shelter from cold, dry winds appears to be most desirable, especially for cattle, and the farmer using part of Tentsmuir Forest, Fife, quoted this specific advantage. His stock are protected from the dry east winds which blow in off the North Sea and without the protection of the tree shelter he mentioned that out-wintering cattle on this site would be impossible.

The combination of wind and precipitation is often said to be an intolerable combination for livestock and access to woodlands under such conditions is generally acknowledged to be desirable. Conifers would probably be more effective shelter, especially from precipitations, though it is frequently mentioned that the heavy and persistent dripping

Plate 8. Sheep resting in the shelter of a birch stand. This photograph was taken in the early morning in January, and the ground was covered with a hard frost.

from saturated foliage, as would occur in a stand during a heavy rainstorm, is not liked by animals.

It would seem that woodlands have great potential use as resting places for livestock (Plate 8). Many authorities have commented on the high radiational heat loss occurring from animals when they are resting, particularly when the ground is wet, frosty or covered with snow. In woodlands, however, a dry bed is often obtainable and both soil and air temperatures during winter are higher than on open ground. Moreover, forest litter, especially when dry, is a poor conductor of heat and the loss of heat by conduction and radiation from an animal lying on such a surface would be minimal, while radiation into space is also reduced by the presence of the forest canopy. These factors do not seem to be realised by the agriculturist.

It has been noticed that in spring the growth of grass in woodlands begins earlier than on open ground. This was particularly marked in the hard spring of 1962, when much of the herbage on open ground was either covered in snow or severely frosted and brown, whereas vegetation under tree cover was already in growth. At Tentsmuir, in Fife, and Spean Bridge and Glen Shirra in Inverness-shire, the advantage of woodlands in protecting vegetation from being scorched by dry east winds in spring received favourable comment. An extension of the growing season of grass under woodland conditions is theoretically possible but this effect will be obscured if an attempt is made to calculate the growing season using mean monthly temperatures. This arises

Plate 9. Feeding racks (right middle-ground) under European larch. Altyre Estates, Morayshire.

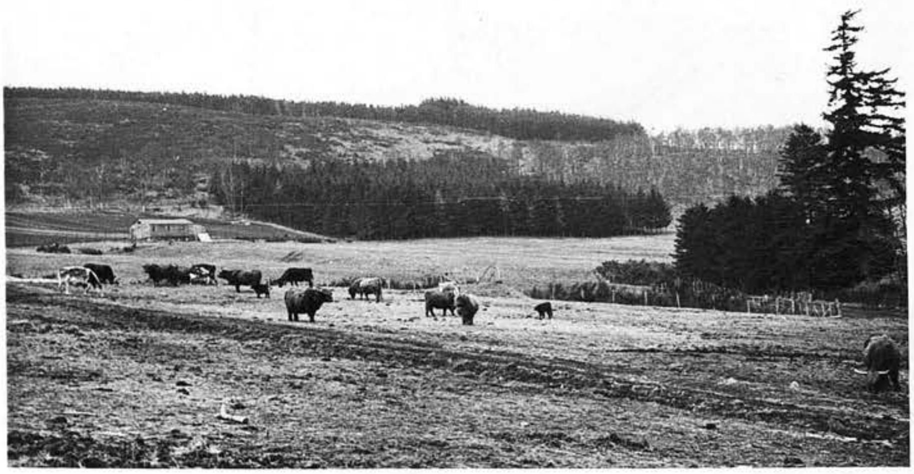


Plate 10. Block of coniferous woodland (centre middle-ground) composed of Douglas fir, Sitka spruce and Scots pine in which cattle are fed during bad weather. Glen Tanar, Aberdeenshire.

because in a woodland environment the mean monthly maxima are depressed more than the mean monthly minima are raised, resulting in a mean monthly temperature which is lower than in open country. But it is the minimum temperature above which growth commences that is important and the fact that a tree cover raises minimum temperatures seems to be of greater significance as far as the growing season is concerned than the depression of maximum temperatures.

It was frequently found that farmers regarded woodlands as valuable alternative wintering grounds, even if there is little grazing available, as it allows stock to be removed from the much-used ley pastures, preventing poaching, and providing a rest period before the sheep and cattle return to them in the spring. On hill farms, where there is likely to be a restricted arable acreage, this factor is of great importance. Often feeding racks are situated under tree shelter (Plate 9) and blocks of coniferous woodland are used as temporary feeding places (Plate 10) when snow is on the ground, the food being distributed throughout the sheltered area.

Coniferous rather than hardwood shelter is preferred by shepherds for lambing grounds as the former provide better shelter, especially when dense and well-brashed, e.g. a spruce wood. Cattle owners do not appear to use such areas as frequently, unless they are near the farm and easily accessible, as constant supervision is necessary at calving time.

At present there is a certain amount of evidence that exposure is a contributory factor in such diseases as pregnancy toxaemia and hypocalcaemic tetany, the incidence being reduced in situations where the animals have access to shelter. Shelter may also be of value in reducing the incidence of hypomagnesaemia which, it has been stated, is high in beef cattle during the winter months when there are rapid changes in weather conditions. It also appears that the risk increases when cattle are suddenly introduced to quick-growing, lush pastures in spring (Observer, 12/2/61). Indeed, one farmer considered that woodland grazing in spring reduced the risk of this disease as the progression from the poor hill-type grasses to woodland vegetation, and then on to the lush, fast-growing ley pastures obviated the sudden introduction to the latter.

2. Disadvantages

For a woodland to be of maximum benefit for out-wintering it should be quickly and easily accessible to man, both on foot and by vehicle, and to stock. Frequently, however, the forest is a long way from the farm and this can so increase the time spent on transporting food to the beasts that the practice becomes uneconomic. This situation was encountered on a farm on the Black Isle, Ross-shire, where the woodland, of open Scots pine with an understorey of juniper, was situated approximately a mile away from the farm buildings. There was no road right into the site and in wet weather access was difficult as the ground became very soft. The woodland was on peat which was easily cut up and poached by the animals' hooves and the food which was placed on the ground soon became fouled and inedible. Even by altering the feeding area from time to time this condition was not improved. This disadvantage, together with the disproportionate amount of time expended on feeding the cattle, led to the abandonment of out-wintering. Instead, a large building containing a self-feed silo will house the beasts on slatted floors during the winter time. The cost of this enterprise was in the region of £5,000 but the farmer considered that in spite of this expenditure in-wintering would be more economic.

A serious disadvantage of out-wintering in woodlands is the loss of dung for manurial purposes. The usual practice during the winter months is to allow both cattle and sheep to graze the foggage on the in-bye land, which benefits from the dung, and if this is deposited elsewhere artificial manures have to be purchased and applied.

It is generally considered that woodland vegetation is neither as nutritious nor so palatable as similar vegetation in the open. Furthermore, the palatability is often adversely affected by contamination with leaf litter.

It has been suggested that there might be difficulties in collecting stock from dense woodlands. This problem appears to be more imaginary than real and has not been encountered by those individuals making use of dense plantations for out-wintering cattle. However, it must be pointed out that the counting and inspection of beasts under these conditions is more time consuming.

Where small blocks of woodland are used for shelter for a long period of time, or in areas that are heavily stocked with animals, it has been mentioned that the risk of infection from nematodes is high, but this hazard would also be experienced with artificial shelter and in-wintering and is not a problem peculiar to out-wintering.

A common disdavantage of allowing sheep into woodlands, especially dense conifers, arises from the loss of wool which gets caught in twigs, snags and bark.

Out-wintering in woodlands will usually involve the farmer in extra fencing commitments, for tree regeneration has to be protected and stock must be prevented from straying on to public roads and into parts of the forest where they are not wanted. Sometimes the Forestry Commission, on leasing part of a forest for out-wintering purposes, insist on the tenant erecting, and maintaining, fences round the area before stock can be turned into the forest. Occasionally cattle grids may be required before stock may use an area. In one instance this was found to be the main factor preventing the use of a woodland for out-wintering. The high specifications required for the grid by the local council necessitated considerable expenditure and it was considered that the ultimate value of the woodland for out-wintering could not justify this expense.

3. Alternatives

Obviously woodlands are not the only aid to out-wintering. The alternatives seem to be: (1) out-wintering with the aid of shelterbelts; (2) out-wintering with the aid of artificial shelter, such as sheds, screens, etc.;

(3) out-wintering without shelter.

Shelterbelts can be used in two ways. Either they can be fenced for all time, in which case stock can only obtain side shelter, or stock may be allowed into the belts once they are established and out of danger from browsing. The former appears to be more common in agricultural areas where land is valuable and intensively used, while the latter dominate in hill country and are used mainly as shelter for sheep. This alternative is indicated where there are no woodlands already in existence and shelter is desirable, although the problems of maintaining such shelter in an optimum condition are considerable.

The use of artifical shelter for out-wintering does not seem to have received much attention in the past. The advantage of small, portable sheds would appear to be that they can be sited where it is most convenient for out-wintering the stock, thus facilitating inspection and hand feeding. The sheds could be moved from time to time to prevent excessive puddling of the soil. However, the risk of disease arising from concentrating animals into such small areas would appear to be higher than if woodlands are used.

Although the writer did not visit any farms where tree shelter did not exist, the general opinion on out-wintering cattle in hill country without shelter indicated that the practice would be difficult and the inference was that under these conditions cattle-rearing would give way to sheep farming. The reason appears to be partly economic. Pure highland cattle, which are hardy and can withstand out-wintering with or without shelter, are slow to mature and therefore the turnover of saleable beasts is small and the profitability of the enterprise is marginal. In order to increase output a faster-maturing animal is required, and this can be obtained by crossing the highland with a faster-maturing breed, such as the shorthorn. The resulting cross-highland progeny still maintain the quality of hardiness but any further crossing for faster-maturity seems to be at the expense of hardiness, and out-wintering then becomes impossible. Thus only the slower-maturing cattle can be produced on hill farms where out-wintering without shelter is a necessity, and since the profitability of such an enterprise seems to be low, sheep farming for which shelter is not essential, would seem to offer greater financial returns. It is generally agreed, however, that both cattle and sheep thrive better if shelter is available.

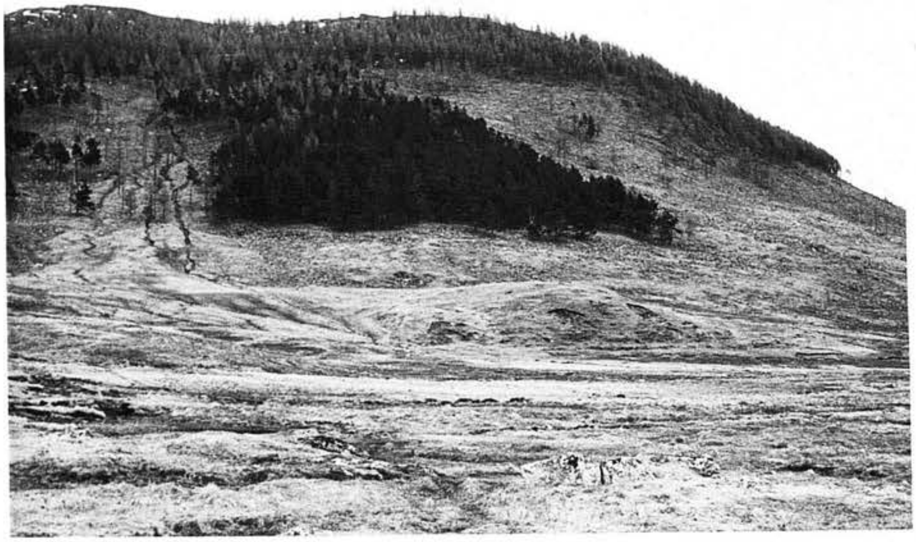


Plate 11. Glen Shirra, Inverness-shire. Scots pine and high elevation larch wood used by sheep during winter months. Soft peat land in foreground, with steep hill slopes strewn with boulders of all sizes in background.

Plate 12. Glen Moriston, Inverness-shire. Birch wood, with discontinuous understorey of juniper and abundant bracken growth.

CHAPTER 10

THE MANAGEMENT OF WOODLANDS FOR OUT-WINTERING FARM STOCK

1. Controlling Factors

For a woodland to be of use for out-wintering it should be reasonably near farm buildings and easily accessible to both stock and man. Where cattle are to use the area the site should also be accessible to vehicles to facilitate the transport and distribution of supplementary winter food.

Accessibility is influenced by the slope and state of the ground in the vicinity of the woodland. Steep slopes (Plate 11), boulder-strewn ground (Plate 12) and soft peaty areas seriously restrict the movement of vehicles and impede hand feeding during the winter months. Gentle to moderate slopes (Plates 13 and 14), easily manoeuvrable by a tractor with trailer, are of more value for out-wintering.

The fertility of the site is also an important controlling factor, for if the area is incapable of supporting a reasonable number of livestock due to the inherent low fertility, then any woodland present is unlikely to be used for out-wintering. This situation occurs in Glen Moriston (Plate 15): steep, boulder-strewn slopes are covered in birch woods, with juniper as a discontinuous understorey (Plates 12 and 16); bracken dominates large areas of hill side and generally the grazing is so poor that the stocking is 1 cow and follower to 25 acres or 1 ewe and lamb to 5 acres. During the winter the cattle have to be fed supplemental rations but the hill ground is too inaccessible for this. Deer are also a problem, by competing for winter

Plate 13. Birch woods, Glen Tanar, Aberdeenshire. Mainly used for out-wintering cattle. Note gentle slopes and wide spacing of trees allowing access to tractor and other machinery.

Plate 14. Open birch woods, showing the type of ground that would present little difficulty to tractor and trailer when hand feeding in winter.

food and shelter. All these factors have militated against out-wintering, in spite of there being adequate tree shelter.

The varied local climatic conditions experienced throughout Scotland will almost certainly lead to different shelter requirements for out-wintering, which occasionally may influence forest management. It was found that in Aberdeenshire, where the winter climate is generally severe, tree shelter is required to be as dense as possible so that the maximum protection is obtained for livestock. Grazing is not so important as supplementary feeding is almost a necessity. But at Spean Bridge, Inverness-shire, shelter and grazing were found to be of equal importance for out-wintering while in Glen Shirra, also in Inverness-shire, an area with a more rigorous climate, there was a bias towards shelter, though grazing was also considered desirable. In the more moderate climate of Argyll grazing is the dominant factor in out-wintering, with shelter of secondary importance.

It seems likely that in many cases forest management can satisfy these demands of the agriculturist but in the case of a predominantly forestry enterprise, this may be difficult. For example, it has been mentioned above that in Argyllshire the general factor for successful out-wintering is an adequate supply of grazeable forage. Should the Forestry Commission in this region lease part of a forest for out-wintering, a programme of heavy thinning for the prime purpose of encouraging grass would be inconsistent with management for economic timber production. However, on private estates, where special objects of management

Plate 15. Typical appearance of hill land in Glen Moriston, Inverness-shire. Infertile peat land in foreground.

Plate 16. Birch woods in Glen Moriston, Inverness-shire. Note dense tree growth which would prevent access to machinery and vehicles, abundant bracken growth and relatively steep slopes. Boulders and large stones are obscured by the bracken.

often include the integration of agriculture and forestry, such a procedure is a definite possibility. It can arise, for example, in circumstances where fire hazard is high and peripheral stands of a large forest area act as fire screens. Forest grazing in these peripheral stands would establish a continuous carpet of short, green and relatively uninflammable herbage which would contribute to reducing the fire danger. But in order to maintain the supply of forage these stands would have to be heavily thinned so that an adequate amount of light could reach the forest floor. In this way agriculture and forestry would have achieved co-existence, each benefitting the other. Usually agriculture will only dominate forestry where farming is the primary enterprise and in such cases it is often found that there is no policy of woodland management. Reclamation will probably reduce the woodland area to a minimum, especially in regions where shelter is of secondary importance for out-wintering.

Providing the general or special objects of management allow it, the shelter requirements for out-wintering will determine the type of woodland that is most desirable. Where shelter of maximum efficiency against all climatic elements is required, dense coniferous high forest would probably be satisfactory. It is when shelter and grazing, or grazing with some shelter, is the desired object that difficulties arise in determining a satisfactory type of woodland, for it is not known at present what reduction in tree cover is necessary to produce a vigorous grass sward

Plate 17. Hillside in Glen Prosen, Angus, covered with open birch woods, providing shelter for sheep.

Plate 18. Glen Prosen, Angus. View to show density of birch illustrated in Plate 17.

while at the same time providing sufficient shelter for out-wintering purposes. One possibility is to maintain a uniform, light tree cover over the whole of a grazing area so that vegetation and shelter is present on all parts of the hill, as shown in Plates 17 to 19. But this type of woodland seems to be too open to provide efficient shelter for cattle. Conifers could be introduced to increase the shelter effect to produce a forest similar to that of the old Caledonian Forest (Plate 20), or they may be planted in small blocks in a matrix of hardwoods. But it has been mentioned that in both types the quality and productivity of herbage would remain at a fairly low level due to the shading by the trees. Plates 21 to 23 show an alternative method. Groups of trees can be dispersed over the area and in the large open spaces between them the grazing could be improved by fertilising and reseeding. This method combines good grazing with adequate shelter. Although the tree species illustrated in the photographs are deciduous, conifers could be used where desired for greater shelter, though it must be pointed out that this would result in a reduction in the grazing acreage, due to the shading out of herbage under the trees. This system seems very adaptable and appears to offer great scope in hill regions where at present land use is not intensive. The size of the open areas can be altered to suit local conditions, varying from mere openings in the forest (Plate 24) to extensive clearings (Plate 25).

2. <u>Effect of tree cover on vegetation</u>

The two most noticeable factors influencing the ground

Plate 19. Ash/alder woodland on part of the common grazings of the township of Carnach, Glen Coe.

Plate 20. Scots pine/birch forest, Glen Strathfarrar, Inverness-shire. A remnant of the Caledonian Forest, in which sheep and cattle are out-wintered.

vegetation in a forest stand are the density of individual tree crowns and the canopy per cent, the former varying with species and depth of crown and the latter with age and treatment. It has been noticed that the growth of grass under the light canopies of birch and larch appears to be almost independent of the canopy and treatment. Plate 26 shows a moderately dense stand of birch in which the amount of vegetation compares favourably with that in the more lightly-stocked area depicted in Plate 18. Plates 27 and 28 indicate the density of swards to be expected under larch.

With all other species of hardwood and conifer the density of ground vegetation seems to be dependent on the age of the stand and its treatment. In summer there appears to be no significant difference between the density of hardwood and conifer canopies. Of the hardwoods, beech is obviously outstanding in the suppression of vegetation though sycamore also casts a particularly heavy shade (Plate 29) and ground vegetation in such stands seems to lack density. Oak high forest with 70% canopy (Plate 30) can drastically inhibit herbage growth, though it has been observed that oak coppice does not cast such a heavy shade (Plates 31 and 32). The Scots pine illustrated in Plate 33 are 35 years old and have received 3 thinnings. The canopy is about 85 to 90% complete and the vegetation grows in patches. This is in contrast to approximately 90 year old Scots pine (Plates 34 and 35), where the canopy is permanently broken, permitting abundant herbage growth. Douglas fir and the spruces do not seem to favour ground vegetation,

Plate 21. Groups of scrub, mainly birch, but containing some oak, rowan and hazel, which has been left for shelter on land that has been reseeded. Taynuilt, Argyll.

Plate 22. Two blocks of European larch, (centre middleground and centre background) with adjacent pasture land used by cattle and sheep. Cawdor, Nairnshire.

except where the latter are very open. Generally speaking, therefore, one can expect abundant vegetation at the time of planting, decreasing gradually under most species to nil by the time the canopy closes, whereupon it will probably remain low until thinnings permanently break the canopy, for during the period of relatively fast growth, with thinnings on a fairly short cycle, the canopy appears to close too quickly for the majority of grasses to become established. As has been mentioned, this does not seem to apply to larch and birch, though frequently in the thicket stage of the latter vegetation is often lacking.

The shading effect of trees is often quoted as a disadvantage for grazing, but as a long term policy it can be used as a tool. It has been noticed that on open ground, where Tufted hair-grass (Deschampsia caespitosa (L.) Beauv.) grows abundantly, it does not seem to be grazed by sheep and rarely by cattle. Under a tree canopy, however, it is practically suppressed, making room for other more palatable and nutritious species. Moreover, where it does occur, the usual coarse, hard leaves appear to be modified by the shade and are much finer and both cattle and sheep graze it hard.

Bracken is a very troublesome weed on many hill grazings as it tends to suppress the grasses. Birch does not seem to have a sufficiently dense canopy, once it is past the small pole stage, to suppress bracken (Plate 36) and often oak high forest and coppice (Plate 32) are now growing too openly to prevent its spread. Manual or mechanical cutting for several years can be used to get rid of it if the ground permits, but in many areas it is likely that neither will be

Plate 23. Interior of larch stand in Plate 22, showing distribution of trees. Cawdor, Nairnshire.

Plate 24. Abundant vegetation growing in an opening in mixed Scots pine, European larch, Norway spruce stand, to which livestock have access. Learney, Aberdeenshire.

possible, as was experienced in Glen Moriston (Plates 12 and 16), where the slopes are generally too steep and stony. Hormone weed killers could be used but the expense would not be justified on this site. A solution to the problem is to turn this and similar poor grazing land over to forestry for a period of one or two rotations, by which time the bracken is likely to have been suppressed. Then the area could be reopened for grazing, which if carefully controlled could prevent the return of bracken. In this case the East of Scotland College of Agriculture have advocated this policy, for the area is too infertile for agricultural use and the cost of any land improvement would be very high.

Contamination of herbage by leaf litter is a problem in some stands. Oak litter is often slow to decay (Plate 30) and in Glen Coe, where part of the common grazing is covered in an Ash/Alder woodland (Plate 19), the tree cover was criticised as the alder litter was said to form a matt over the ground which impeded the growth of grass. This was also observed on another occasion on Loch Tay side, where it was also noticed that ash litter decayed fairly quickly. The contaminating effect of Scots pine needles appears to vary with the age and density of the tree cover. In the stages up to small timber size herbage is often smothered in needles yet once the trees proceed into the large timber sizes contamination seems to decrease. This may be due to the higher rate of needle cast and renewal in the younger stages of growth. The spruces have been mentioned as being

Plate 25. An extensive clearing in oak wood followed by fertilising and surface seeding to improve the grazing. Taynuilt, Argyllshire.

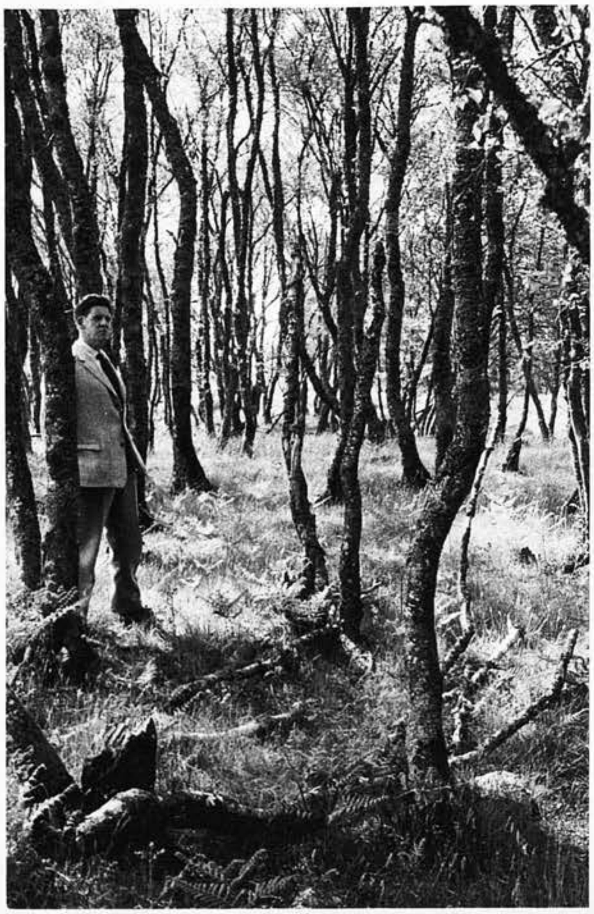


Plate 26.
Good growth of grass in a moderately dense stand of birch, with some hazel. Taynuilt, Argyllshire.

particularly dangerous to livestock on account of their sharp needles. Birch and larch appear to have the least effect in contaminating herbage.

Vegetation in woodlands is commonly criticised for its inferior quality and palatability, as well as its lack of density. It seems to be true that the density, and hence the quantity, is reduced by a tree cover. Palatability, however, is influenced by so many factors that it is not possible to generalise on this issue. It seems that one must consider this question by stating the context of the term, and if one limits this to "palatability during the winter months" it is doubtful whether the palatability of woodland grasses is less than herbage on the open hill. In fact the word ceases to have much meaning in winter for only too often livestock are forced to eat anything and everything that is within their reach. As far as quality is concerned this is a moot point. There seems to be every reason why woodland vegetation should be more nutritious than vegetation on open ground. The roots of trees can bring up nutrients from deep down in the soil or bedrock and some of these are returned to the soil surface in the leaf fall. Woodland vegetation can then assimilate these nutrients which are not available to the herbage on open ground. Thus a tree cover should be able to maintain, perhaps even increase, the fertility of the soil and this should be reflected in the chemical composition of the ground vegetation. In order to test the latter assumption it was decided that in the areas for detailed study analysis of

Plate 27. European larch, Cawdor, Nairnshire, showing the type of sward to be expected.

Plate 28. Abundant vegetation under European larch, to be grazed for the first time this year by sheep. Drummond Hill Forest, Perthshire.

herbage would be carried out on samples from under the tree cover and compared with samples from the adjacent open ground. However, during the winter months, when most of the areas were studied, the lack of vegetation on open ground prevented enough herbage being collected and comparative sampling was therefore impracticable. This accounts for only two areas being sampled. Area 1 was on the south side of Caerketton Hill, which is at the eastern end of the Pentland Hills. The soil was a brown earth of gravelly-loam texture. The hill vegetation was an Agrostis/Festuca type with some clover, though only grasses were included in the sample. The woodland vegetation was similar in composition, with the exception of clover, which was replaced by Poa species. Grasses only were sampled from under a pure sycamore stand and a mixed coniferous stand composed of European larch, Scots pine, spruces and an occasional birch. Area 2 was situated in Tentsmuir Forest, Fife, on the north side of the Eden estuary. The soil was of sandy texture with a well-developed podsol. The tree cover consisted of Scots and Corsican pine and the grass species were mainly Holcus, Poa and Agrostis. Growth outside the forest at sampling time was so far behind that inside the forest that barely enough herbage was collected for sampling. The grass species were similar to the forest area though the proportion of Agrostis was higher and Festuca was also present. The results of the Analyses are as follows:

Plate 29. Sycamore coppice, showing lack of vegetation due to dense shade cast by the canopy in summer. Boghall Plantation, Midlothian.

Plate 30.
Killiechonate oakwood, Spean Bridge, Inverness-shire. Open to livestock but note the sparse vegetation and the heavy matt of oak leaves.

	Date of collection	Crude fibre	Crude protein	Ca	P	Mg	Ash	Cu	Mn	Fe
		Per cent dry matter						p.p.m		
Area 1 Mixed conifer stand	8/5/61	21.7	25.9	0.42	0.37	0.202	10.6	7.3	78	324
Sycamore stand	4/5/61	22.7	25.1	0.46	0.29	0.162	7.8	<1.0	13	71
Open ground	5/5/61	21.6	21.2	0.44	0.24	0.190	6.9	6.8	26	146
Area 2 Scots and Corsican pine stands	5/5/62	22.8	28.2	0.25	0.20	0.300	10.7	10.7	530	117
Open ground	5/5/62	19.7	28.3	0.34	0.21	0.190	7.9	13.1	138	113

On the whole there is little significant difference between these samples. The reason for the very low Cu, Mn and Fe contents in the sample from the sycamore stand in Area 1 is difficult to explain. It was thought that possibly the sycamore litter might be deficient in these elements and this was therefore analysed with the following results: Cu = 5.8 p.p.m.; Mn = 442 p.p.m.; Fe = 265 p.p.m. These figures are similar to what one normally obtains with herbage samples, except that the manganese content is somewhat higher. Therefore the cause would not seem to lie here, though this assumes that the whole of the Cu, Mn and Fe content of the litter becomes available for growth, which is doubtful. A more likely explanation is the fact that the sycamore stand is on very steep slopes (average gradient 1 in 2), resulting in litter being easily blown off the area or into any hollows in the ground. A contributory factor would probably be strong leaching on account of the steep slopes. It is also interesting to note the difference

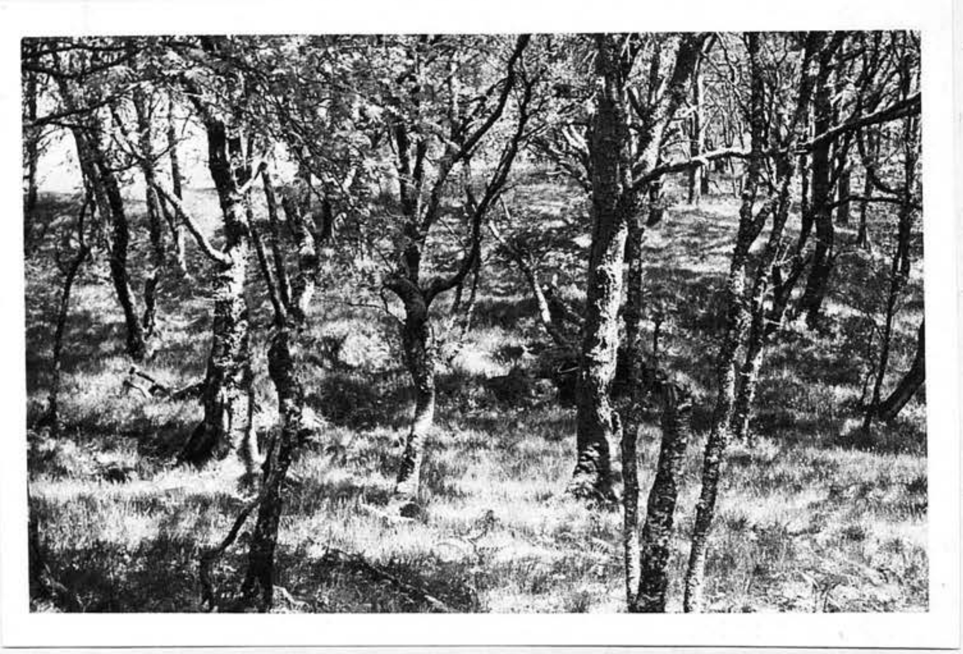


Plate 31. Oak coppice with some rowan under which there is a good sward. Taynuilt, Argyllshire.

Plate 32. Oak coppice, containing some rowan and birch. Abundant bracken growth tends to suppress the grasses. Taynuilt, Argyllshire.

in Mg content of the two samples from Area 2, for it was in this area that a farmer considered the woodland vegetation valuable in decreasing the incidence of hypomagnesaemia in spring. Possibly the favourable Mg content of the woodland vegetation accounts for this. However, with so few areas sampled this experiment cannot be regarded as proving anything but it suggests that the quality of woodland grasses is not inferior to those on open ground and agrees with Ovington's (1956) results and François' (1953) observations. On the other hand Guise (1939) and Hawley and Stickel (1959) state that the opposite is true. The subject seems to merit further study.

Sampling only grasses from wooded and non-wooded environments will not give a true picture of the store of nutrients from which an animal can draw at will. Many of the herbs are richer than grasses in certain elements, as has been shown by Fagan and Watkins (1932) and Stapledon (1936), and the advantage of a woodland environment is that often the variety of herbs within it is greater than on open hill land and the opportunity for satisfying an animal's nutrient requirement is therefore theoretically greater.

3. Effect of stock on stand and vegetation

(i) Density and distribution. At present the number of animals that a woodland can feed during the winter is assessed from experience. The figure will naturally be higher for the shorter period of winter than if stocking was being assessed for yearlong use. But it has been suggested

Plate 33. 35 year old Scots pine, Tentsmuir Forest, Fife., in which Galloway cattle are out-wintered. 85 - 90% canopy, herbage rather patchy and somewhat contaminated by litter.

Plate 34. Scots pine stand, approximately 90 years old. Note lush growth of <u>Holcus</u> which is uncontaminated by litter. Accessible to livestock. Crailing, Roxburghshire.

that in arriving at this figure an allowance should be made for deer, especially in the Highlands, where any form of shelter is bound to be used by these animals. For example, if the assessed stocking capacity of a woodland is 1 cow to 5 acres, this figure could be reduced to, say, 1 cow per 6 or $6\frac{1}{2}$ acres as a safety factor to prevent over-grazing by the influx of deer into the area. In addition, the American system of a variable stocking rate from year to year, depending on the available forage, would appear to be useful in keeping damage from browsing at a minimum. Plate 37 shows an area of Rothiemurchus Forest, in which Highland cattle, sheep, red and roe deer, hares and rabbits all exist, yet natural regeneration is abundant. This is due to strict control of the density of livestock throughout the area.

It is potentially dangerous to rely on the farmer to assess the stocking capacity of a woodland because there is a tendency to put the figure automatically at the size of the herd. This situation existed on one farm in Aberdeenshire, where a herd of 50 hill cattle were brought from the hill to lower ground to be out-wintered in a small block of woodland of 17 acres. This is a density of 3 beasts per acre and the owner casually commented on the fact that the trees were dying. The agriculturist should discard the conception of unmanaged woodlands as "waste ground", to be used freely and haphazardly as long as the tree cover persists. In any well-managed system of out-wintering, the stocking capacity of a woodland should be assessed on the same principle as that for pasture land and hill grazings. It

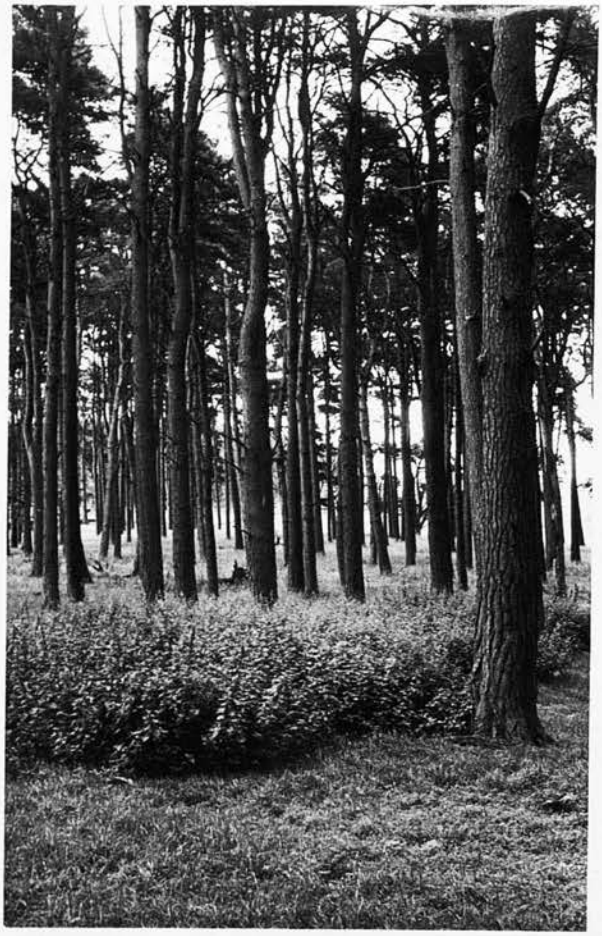


Plate 35. Another view of Scots pine stand shown in previous plate.

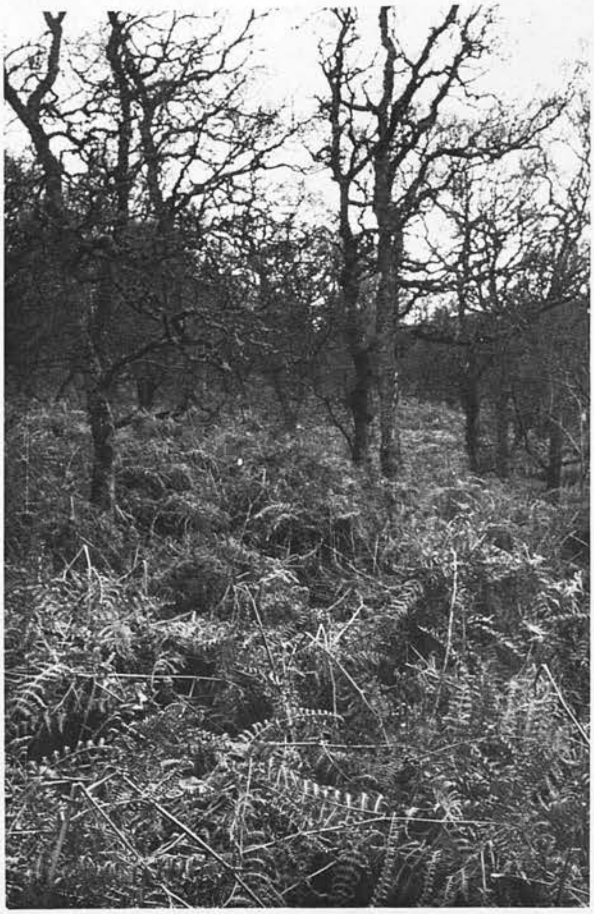


Plate 36. Very open birch high forest with abundant bracken as ground flora, making the area useless for grazing. Glen Prosen, Angus.

Plate 37. Rothiemurchus Forest, Inverness-shire, a remnant of the old Caledonian Forest. Note the regeneration of all sizes. The forest is open to deer, cattle, sheep, hares and rabbits.

is suggested that the forester (where applicable) should make his own assessment or at least check that the stocking capacity envisaged by the farmer is a realistic figure.

It is important to ensure correct distribution of stock over the ground to prevent concentration in some areas while others remain unused. This is likely to occur where herbage is not distributed evenly throughout a woodland. There appears to be no solution to this problem at present, apart from herding, which is not practicable. When hand feeding begins the situation can be improved if the food is put in the unused parts of the wood and the position changed at short intervals.

(ii) Damage to trees. In general, it seems that sheep can be regarded as more destructive than cattle to woodlands in the younger stages through browsing. Opinions seemed to agree in that sheep are more inclined to eat woody vegetation than cattle, which prefer grasses if available. Plate 55 shows an area of checked Corsican pine used by cattle during winter. The trees are within easy reach of browsing animals yet practically no damage has occurred. But Plates 38 to 40 demonstrate the damage that can be inflicted on young trees by sheep. Not only would foliage be browsed but complete barking is a possibility. However, over-stocking with cattle can be equally harmful to tree growth. Plates 41 and 42 show the low, flat growth habit of juniper under excessive browsing by cattle and sheep.

Cattle appear to be capable of causing more damage to

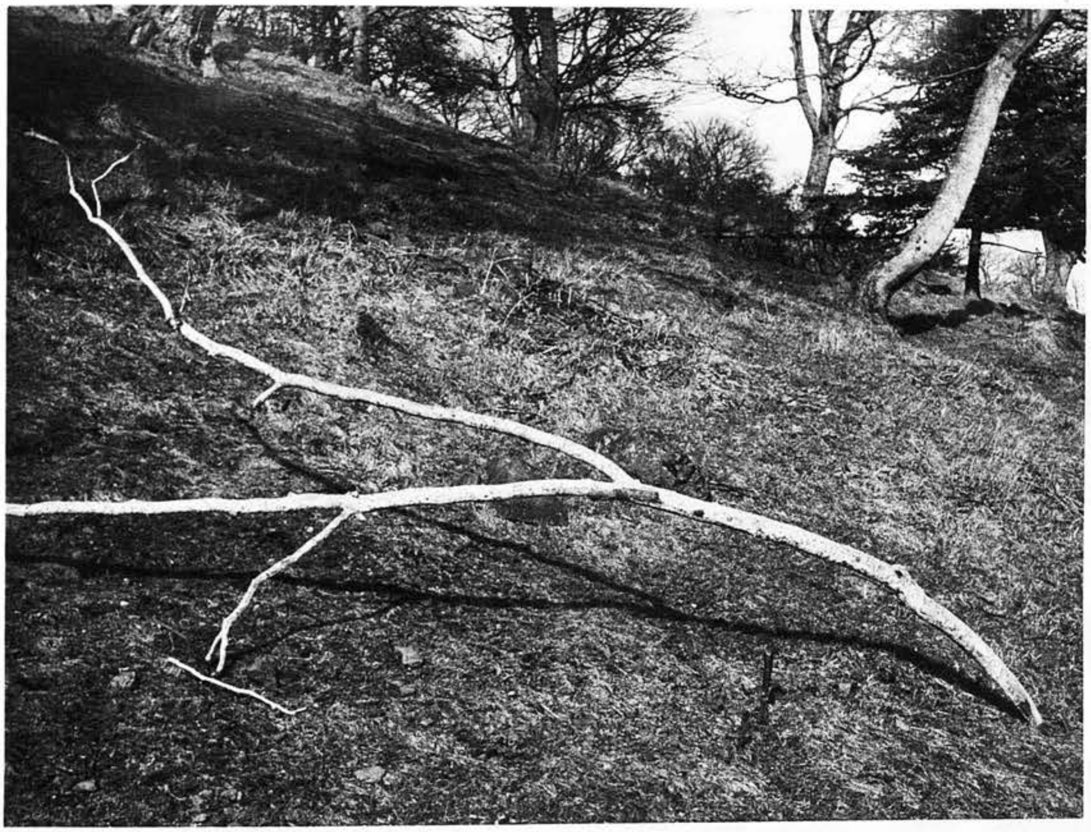


Plate 38. Sycamore branch that has been completely barked by sheep.

Plate 39. Close up of sycamore branch in above Plate, showing teeth marks of sheep.

older trees than sheep. Plate 43 shows a Norway spruce stripped of its bark on one side. This was attributed to pure mischievousness of the cattle using this plantation. Trees with branches down to a low level were not damaged in this way (Plate 44). Where the wound was not large an abundant resin flow had helped the wound to heal but where the damage was extensive or girdled the tree it has led to attack by insects (Dryocetes autographus) resulting in windsnap at the point of infection (Plate 45).

Cattle seem to be very fond of rubbing their heads against trees and Plates 46 to 48 indicate the damage that may result. This is likely to lead to windsnap if the damage is extensive.

Cattle that have not been dehorned can inflict wounds on thin-barked trees (Plate 49). It is doubtful whether this damage is intentional but nevertheless it could be serious in that it provides an entry for fungus.

As cattle are very much larger and heavier animals than sheep they can cause more damage to tree roots. Plate 50 shows how soil and litter is trampled away from surface roots which are then barked by the animals' hooves, providing an entry for fungi. This effect has been observed with sheep only along their regular tracks.

(iii) Other damage. American workers have established that considerable detrimental soil changes occur when livestock are grazed in woodlands. While this may hold good for British conditions there does not appear to be any published data on the subject in this country. As the out-

Plate 40. Gorse bushes eaten into weird shapes by sheep. Sutherland.

wintering of livestock involves the use of woodlands at a time when the soil is usually most vulnerable to damage the problem should be studied in greater detail before outwintering in woodlands can be safely recommended.

Lull (1959) mentions that forest litter and humus have a cushioning effect which may give some protection against soil compaction. In the mixed conifer plantation illustrated in Plate 51 it can be seen that cattle have denuded a small area of its litter and humus layers, exposing the mineral soil. Such conditions could result in quicker and more efficient soil compaction and even puddling of the soil, reducing the air spaces and decreasing the rate of infiltration of water. It is therefore quite likely that surface roots may be killed which would cause a reduction in the rate of growth.

In several plantations used by livestock it was noticed that there was an appreciable accumulation of dung. In view of Russell's (1961) comments it appears that one should be aware of the possible dangers of excessive manuring, especially in conifer plantations. The high concentration of ammonia in the soil from dung and urine may be toxic to tree roots.

It is apparent that where livestock have access to woodlands they damage drains and ditches. This is often caused by animals in their efforts to drink the water or to cross the ditch. Steps can be taken to avoid this by providing special drinking places with sloping banks and constructing an adequate number of crossing places.

Plate 41. Juniper suffering from over-grazing by cattle and sheep. Glen Tanar, Aberdeenshire.

Plate 42. Prostrate growth form of severely-browsed juniper. Glen Tanar, Aberdeenshire.

However, even then damage is likely to occur and it will have to be accepted if woodlands are used for out-wintering. Repair work will then become routine each year after livestock have been removed from the plantations.

(iv) Vegetation. Undoubtedly the practice of out-wintering livestock in woodlands can be of great benefit in reducing a fire hazard. Cattle are probably more use than sheep in this respect as they are less selective in their grazing habits and will eat long, rank grass that sheep will not touch. In Tentsmuir Forest, Fife, grazing with cattle has been found to reduce the accumulation of dead and inflammable grass leaves (Plate 52) and promote a shorter growth of green and relatively uninflammable herbage (Plate 53). Also slash is broken up and distributed throughout the stands. Plate 54 shows the type of vegetation encountered in this forest (a mixture of *Holcus*, *Festuca*, *Agrostis*, *Calluna* and *Molinia*). This area is ungrazed, while Plate 55 shows the marked reduction in fire hazard when grazing is allowed during the winter months, though the latter area is not strictly comparable in vegetation, which is predominantly marram grass.

The fire danger among young trees is also high in this forest as weed growth is prolific. A strip clear-felling system is used with artificial planting of the cleared areas. Heavy weed growth appears by the second year after felling and to reduce it is a problem. Obviously grazing by any livestock during winter would be dangerous, while control of weed growth by cutting is expensive and the use of hormone

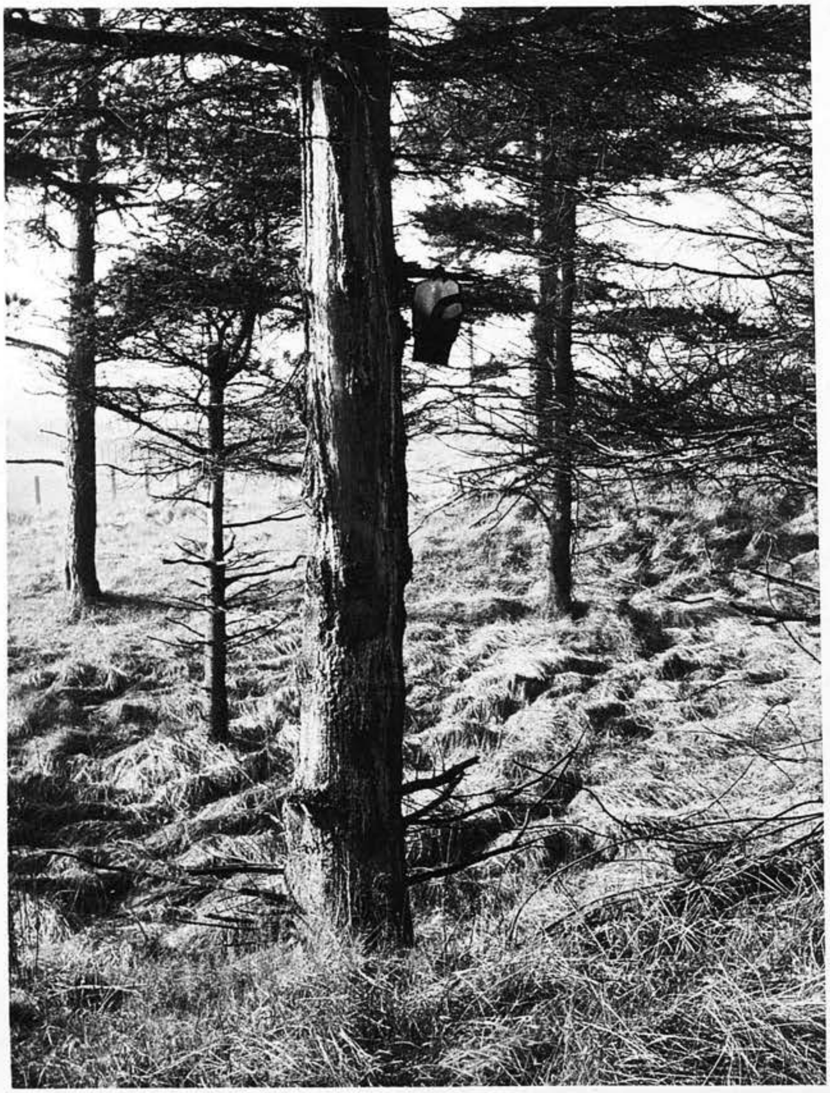


Plate 43. Large wound on Norway spruce, caused by cattle stripping off the bark. West Lothian.

weed killers is both expensive and dangerous to young trees. The following method is suggested for trial in such cases. Grazing must not take place until the young trees are clearly distinguishable amongst the weed growth, which in this area involves a period of 3 to 4 years after planting (with pines). Thereafter, <u>summer</u> grazing with <u>cattle only</u> could be tried out. This is based on the general observations that cattle do not intentionally or preferentially graze woody growth while there is abundant herbaceous material on which to feed, as would be the case during the summer months. Allowing grazing only after trees are clearly visible should ensure that cattle do not browse the trees unintentionally. When the regeneration is well established summer grazing could then give way to winter grazing.

(v) Season of use. Many woodland areas, although specifically used for out-wintering, are accessible to livestock throughout the year. Wherever possible this practice should be discontinued. Until the duration and effects of soil damage are better known there is every reason to keep livestock out of woodlands as much as possible. Moreover, there is usually abundant food for livestock on the open hill in summer and this should be utilised to the full, protecting the herbage in woodlands so that there is a plentiful supply of winter food and adequate clean grazing ground.

4. <u>Fencing</u>

It is practically inevitable that fencing will be required if woodlands are to be used for out-wintering.

Plate 44. Cattle damage in Norway spruce stand. Note how tree on left of middleground has had its bark stripped while that on right of middleground, with branches almost to ground level, has escaped injury. West Lothian.

Plate 45. Windsnap has occurred at the point of attack by beetles (Dryocetes autographus) as a result of bark damage by cattle. West Lothian.

Stock will usually have to be confined to a particular area of the forest or prevented from straying on to busy main roads. As efficient fencing is expensive, it is naturally a deterrent to out-wintering in woodlands.

If woodlands are to be divided up permanently and used on some form of rotational system to allow both regeneration and pasture improvement, the conventional post-and-wire fence can be used and where cattle only are to be out-wintered 3 strands of barbed wire seem to suffice. However, in the smaller blocks of woodland, where rotational use might be impracticable, and small groups of regeneration have to be protected, the cost of such fencing would be prohibitive. Electric fencing has been suggested as an alternative but this is said to be ineffective against sheep as their wool acts as an insulator, while it also needs constant inspection to prevent the electrified wire being earthed by branches and twigs which fall on to it. But electric fencing could probably be used successfully in some circumstances.

Where groups of regeneration need to be protected it may be possible to use tensioned galvanised wire with the large peripheral trees surrounding the regeneration area acting as stobs. Hardwood blocks could be used to prevent the trees being damaged by the tensioned wires, which should be passed through a hole in the blocks to prevent the blocks from slipping out from under the wires when the trees are swaying in a wind. The wires could be tensioned using any of the normal individual wire tensioners. This method

Plate 46.
Scots pine damaged by the rubbing of cattle. Glen Shirra, Inverness-shire.

Plate 47.
<u>Abies</u> permanently damaged by cattle. Glen Shirra, Inverness-shire.

would seem to be dependent on the peripheral trees being more or less vertical, otherwise the tensioned wires would not stay in position, and also on there being a sufficient number of trees to act as stobs.

The new polythene and nylon nettings may prove extremely useful providing they are strong and reasonably durable. This material is light enough to require the minimum of supporting posts, thus considerably reducing erection costs, or it could be hitched on or tied to, trees surrounding an area to be protected, thereby cutting out the cost of posts altogether. It has also been suggested that this material should be used in the form of several narrow strips of about 9 ins. in width, rather than in one complete section of $3\frac{1}{2}$ to 4 feet wide. This is based on an observation that cattle seem to be able to jump a $3\frac{1}{2}$ foot wire netting fence whereas they cannot jump a 3-strand barbed wire fence of the same height. The reason for this is unknown but if this method was found satisfactory there would be a further reduction in costs.

Another form of protection which has proved efficient is that shown in Plate 56. In a mixed sycamore coppice/spruce stand groups of sycamore regeneration were protected by heaping up around them dead spruce lop-and-top, of which there was a plentiful supply in the plantation. Sheep have access to the woodland all the year round and cattle during the summer months. The barrier was erected in spring and visited occasionally until the autumn. It had effectively kept out all animals. But it must be pointed out that firstly, there was nothing inside the protected area to

Plate 48.
Douglas fir barked by cattle rubbing. Glen Shirra, Inverness-shire.

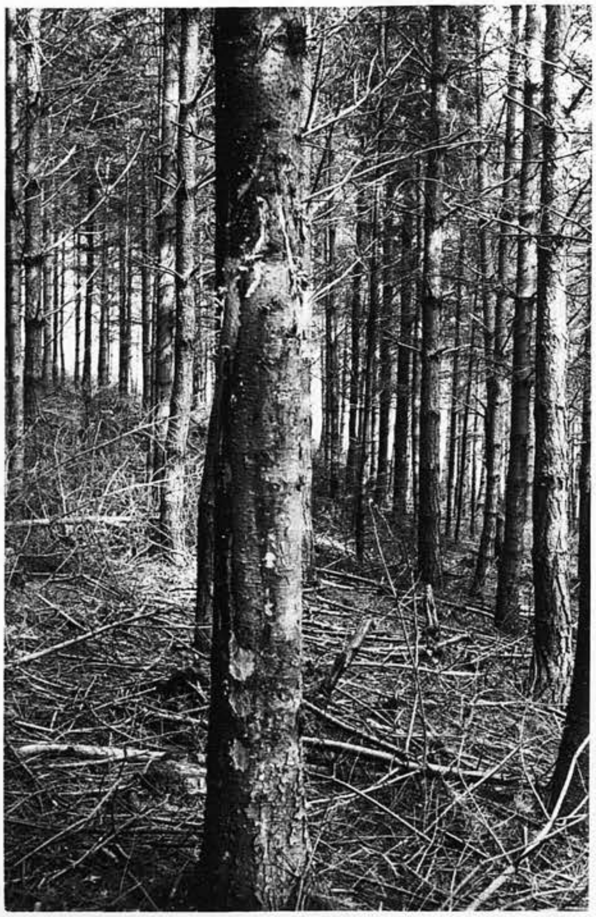


Plate 49.
Spruce damaged by the horns of Highland cattle. Glen Tanar, Aberdeenshire.

encourage livestock to break in, apart from seedlings in an otherwise bare soil, and secondly, there was no shortage of food during the summer. It is unlikely that the amount of slash used in this instance would be sufficient protection for young plants against hungry animals during a hard winter. Yet where abundant slash is available such protection would be cheap and would solve the problem of disposing of lop-and-top.

5. Silvicultural systems

To obtain regeneration in a woodland simultaneously with the presence of livestock is an obvious problem. A silvicultural system is required which will allow a sufficient area of regeneration to be protected from all animals while at the same time permitting the remaining woodland to be used for out-wintering. The difficulties of such a scheme become more acute with the smaller woodlands, for in order to obtain a suitable acreage of regeneration the portion of tree cover remaining open for shelter may have to be reduced to a size where excessive concentration of stock becomes unavoidable, and the risk of damage to the plantation is therefore increased. Conversely, if the accessible area of woodland is kept more or less constant, then adequate regeneration cannot be obtained.

(i) Clear-felling system. Forests being managed under this system would appear to be suitable for out-wintering. Areas undergoing regeneration would need protection for several years, probably 10 to 20, depending on the species, after which time they could be reopened to grazing and further areas enclosed. It is suggested that out-wintering

Plate 50. Slash and litter have been trampled away from the roots of this spruce, which have then been damaged by the hooves of the cattle. Glen Tanar, Aberdeenshire.

Plate 51. Cattle have concentrated in this small area, denuding it of practically all litter and humus and exposing the soil. Glen Tanar, Aberdeenshire.

commence in the older stands where there is likely to be more forage and the trees less liable to be harmed by animals.

Clear-felling of whole compartments should be more favourable to out-wintering as in this way regeneration is concentrated and the cost of fencing kept at a minimum. Complicated felling plans with many felling series and annual coupes would mean higher fencing costs which would not be justified purely for out-wintering.

The large area of birch scrub in the Highlands could well be treated on a clear-felling system. Apart from being well-suited to such a system, birch has little market value and would be unable to justify the cost of less intensive exploitation, unless enriched with more valuable species.

(ii) Shelterwood systems.

(a) The Uniform system. In the larch forests of the High Alps of France, this system has been used successfully to combine forestry and grazing. The whole of a forest cannot be open to livestock at one time for there will always be some areas under regeneration.

Out-wintering in the stands about to receive a seeding felling would probably be desirable where natural regeneration is envisaged, as this would help to break up any litter layers and expose the mineral soil. Thereafter stock would have to be excluded from the oldest stands until seeding, secondary and final fellings have been completed and possibly for a further period after that to allow for com-

Plate 52.
Abundant growth of Reed Canary-grass (Phalaris arundinacea L.) under dense Scots pine, presenting a high fire hazard. Tentsmuir Forest, Fife.

Plate 53.
Relatively uninflammable short, green grass under Scots pine; a result of grazing.

plete establishment and sufficient growth to prevent browsing of leading shoots.

This system would appear to be practicable for smaller blocks of woodland, especially where natural regeneration is to be used. The woodland can be divided into two or more parts of which one will always be closed for regeneration purposes, the time varying according to the regeneration period. If the woodland is small, only two sections may be possible, one for the regeneration and the other for out-wintering. Where further subdivision is practicable this would allow some form of rotational use in the grazed area, which generally seems desirable, as grazing the same area in spring each year is said to weaken the grasses. Furthermore, with the present lack of knowledge on the duration of grazing required to bring about soil compaction, it would be wiser to rotate the areas used for out-wintering so that part of a woodland remains unused each year. Permanent subdivision of the woodland by fencing would be necessary, for when regeneration is complete the fences would still be required for confining the stock to that portion of the forest where out-wintering is to take place.

(b) Other Shelterwood systems. Included under this heading are the Group system, Irregular Shelterwood system and the various strip systems. Where large forests are concerned, out-wintering would be compatible with all these systems provided it is confined to those areas not undergoing regeneration. Herein lies the disadvantage. Nearly all of these systems would involve fencing relatively

Plate 54. Ungrazed area of Tentsmuir Forest, Fife, showing the type of highly inflammable vegetation that exists.

Plate 55. An area, in the same forest, in which cattle are out-wintered. Note the very short sward and complete lack of accumulated dead grass leaves.

small areas of regeneration, with new ones frequently being added, and the cost would be high. Therefore, unless conditions indicate that one of these systems should be used, they appear to offer no advantage over some form of selection system.

(iii) Selection systems. For small woodlands both stem-by-stem and group selection seem to be ideal as they aim at continuous regeneration over the whole of a woodland. However, stem-by-stem selection would probably be incompatible with out-wintering because there would always be young growth vulnerable to browsing damage, with the ever-present danger of regeneration falling behind exploitation. Moreover, it is likely that forage would always be minimal under such a system due to the maintenance of a continuous tree canopy. This disadvantage also exists, though to a lesser degree, with the group selection system and therefore it would probably be more applicable in those regions where continuous shelter, rather than grazing, is required for out-wintering.

The main problem with a group selection system is that of protecting the developing groups of regeneration. Numerous groups of irregular shapes will incur high fencing costs if the conventional post-and-wire fence is used. But with the advent of the new polythene and nylon nettings this difficulty could be surmounted. Methods of using this and other material have been suggested in Section 4 of this Chapter.

(iv) Coppice systems. François (1953) has stated that

Plate 56. Sycamore regeneration was efficiently protected by this crude barrier constructed of dead spruce lop-and-top. Boghall Plantation, Midlothian.

coppice is more favourable to grazing than high forest as it allows more light to reach the forest floor so that there is usually a greater growth of grass. This system should therefore be of use where grazing, rather than shelter, is required for out-wintering. It has the advantage that regeneration from coppice takes less time to outgrow danger from browsing as the root system is already established. But at present there is little demand for the produce of coppice woodlands and landowners are reluctant to spend time on managing such areas for no monetary return. This appears to be the main reason why so much of the birch, oak and alder coppice throughout Scotland is left untouched.

However, on hill farms, where the limiting factor for the production of store cattle is usually winter food, there is an indication that coppice woodlands may be able to yield a useful supply of food from foliage. Urquhart (1953) has mentioned this in connection with the extensive coppices of oak, ash and birch in the southwest of Scotland and notes that the protein content of birch, elm and alder leaves varies from 16 to 20%, compared with that of heather which is only 12%. Nehring and Schütte (1950) in Germany have investigated the composition and fodder value of the foliage and twigs of many hardwood species. Initial experiments, concerned with the change in chemical composition during the period of growth, showed that foliage is characterised by a favourable Ca and P content, though the latter is low in twigs. Interspecific differences in mineral content, particularly K, are very great. The crude protein content and digestibility declines from spring to autumn while the amount of fibrous material increases slightly during the same period. Protein digestibility varies from 80% in elder leaves to 40% in beech and birch leaves, but it is generally low in twigs. For large scale feeding these authors recommend leafy twigs, for which the best time of collection is generally late June to mid-August, though somewhat earlier for beech and birch. The species tested were placed in the following descending order of fodder value, as determined by chemical composition and protein digestibility: (1) Elder; (2) Large-leaved lime, ash, aspen; (3) Sycamore, English elm, pedunculate oak, rowan; (4) Hornbeam, common alder; (5) Beech, verrucose birch.

Later experiments by Nehring and Schram (1951 a) were concerned with determining the digestibility (by laboratory and feeding tests) of foliage and twigs in the green, ensilaged and dried states. They have found that the ensilage of finely cut twigs presents no difficulties and the ensilaged fodder is readily eaten by animals. Foliage and twigs cut early in the year were accepted by animals without great difficulty but considerable differences appeared between species for older leaves and twigs. Leafy twigs of maple, lime and poplar had the highest digestibility, the value being the same as for average quality hay. The following table shows the palatability of leaves and twigs of the various hardwoods tested by Nehring and Schram.

PALATABILITY:-

Good	Moderate	Bad or nil
Ash lvs	Elder lvs and twigs	Beech lvs
Elm lvs	Hornbeam lvs	Birch lvs and twigs
Norway maple lvs and twigs	Pedunc. oak lvs	Beech twigs
Aspen lvs	Black alder lvs	
Poplar lvs and twigs (*Populus canadensis*)		

Nehring and Schram (1951 b) have also found that shed leaves have a lower protein and a higher fibre content than green leaves, with the protein digestibility of the former being very small. But the fodder value of winter twigs is higher than that of summer twigs, the best species being elder and ash and the worst birch and oak. The protein digestibility is generally high and these authors state that the more digestible winter twigs (poplar and beech) have a fodder value equal to that of winter straw.

It is noteworthy that all the species mentioned regenerate freely from coppice or suckers and many are common in the Highlands.

(v) Conversion systems. The majority of birch and oak coppices inspected on the tours would probably not be capable of regenerating from coppice as they are too old. They seem to be the remnants of the woods that once supplied the charcoal and tan bark industries, which became uneconomic in the latter half of the 19th century. Regeneration of the birch areas requires immediate attention for the trees are at their maximum life span and the tree cover is disappearing relatively quickly. With the oak there is less urgency, for the longevity of this species is considerably greater than birch.

Many authorities favour the retention of birch in the Highlands in order to maintain the fertility of the hill grazing. However, birch woodland is generally uneconomic to manage as the produce does not yield a financial return. Furthermore, the shelter from light-canopied birch trees in winter does not appear to be very substantial. It has been suggested, therefore, that the large areas of birch scrub could be enriched with blocks of conifers, from which useful timber and shelter could be obtained, while still keeping the birch for the maintenance of fertility. Small blocks of the latter species could be clear-felled and the ground cultivated to break up any grass sod so that natural regeneration could take place from the surrounding mother trees.

The timber from coppice oak is generally of poor quality and unsaleable. Conversion to some other species will therefore be necessary and in order to prevent total exclusion of livestock from these areas during winter, some form of group regeneration would seem to be necessary.

6. Grazing systems and improvements

There would appear to be every advantage in dividing woodlands up into sections for out-wintering wherever possible. It would ensure a more even distribution of stock throughout a woodland, would make rotational use possible and allow a part to be 'rested' occasionally. Rotational use seems desirable because early spring grazing in the same areas each year tends to weaken the herbage. Also resting a section of woodland from time to time would probably reduce the damage to the soil.

The division of woodlands will be dependent on their size. Small woodlands will probably not be capable of division into more than two parts, one for out-wintering and one for regeneration. In others, however, three parts would be better, to allow for a rotational grazing system. One part, or its equivalent area, must be devoted to regeneration, while out-wintering would alternate on the other two sections so that each would be used every other year. As the size of woodland increases the number of subdivisions and the complexity of grazing systems can be increased to suit the individual, but this would increase the cost of fencing.

On some estates the improvement of grazing under a tree cover, or in gaps in the tree cover, might be considered worthwhile. This can be achieved by the application of fertilisers alone, which is the cheapest method, or it can be supplemented by surface seeding, and also cultivation of the soil, each operation increasing the cost.

It has been suggested that the large areas of birch scrub (Plates 16 and 17) could be improved for grazing by making clearings in the woodland, of at least 1 acre to be economic, and improving the herbage in these clearings by the application of fertilisers and surface seeding. The trees separating each clearing would be used by livestock for shelter and could possibly be enriched with conifers to provide useful timber and better shelter.

Another possibility is to thin parts of a woodland heavily and improve the pasture under these areas, the remaining unthinned portion providing the shelter. Such a system was found to be in operation on one of the estates visited in Argyll, and has been described by MacLeod (1960). The woodland consisted of oak, birch, rowan and hazel and the vegetation mainly bents and fescues on the drier ground, with Molinia on the damp sites. Bracken was abundant throughout the woodland. Initial treatment consisted of removing the birch, rowan and hazel (Plates 26 and 31) on those areas accessible to machinery and thinning the oak out heavily to allow for easy passage of the machinery. Thereafter the bracken was cut by hand and 3 tons of ground limestone and 1 ton of basic slag were applied per acre. This was transported in bulk and spread by shovels from a tractor and trailer. The improvement to the vegetation was considerable but the cost of felling the oak, for which there was no market, was high, about £20 per acre. The treatment was subsequently modified, the oak being thinned partly by direct removal and partly by ring-barking (Plate 57). This reduced costs by about £3 per acre. Surface seeding by a mechanical seeder was also employed in later treatments, the seeds mixture containing 10 lb. Scotia Cocksfoot, 10 lb. S. 143 Cocksfoot and 1 lb. New Zealand White Clover, being a total of 21 lb. of seed per acre. The cost of fertiliser and seed, after deduction of subsidies, amounted to £9 per acre. The blocks of original

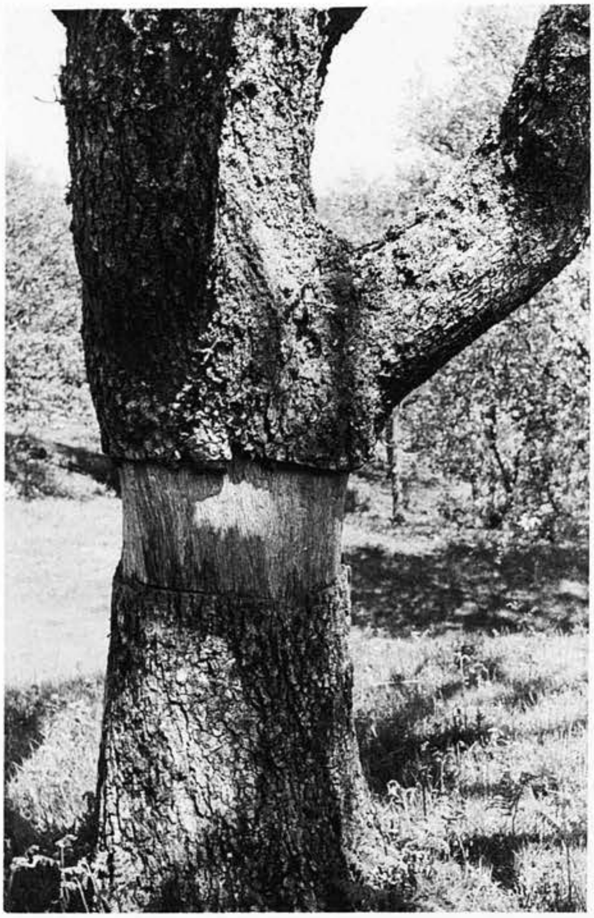


Plate 57. Oak tree ring-barked. Taynuilt, Argyllshire.

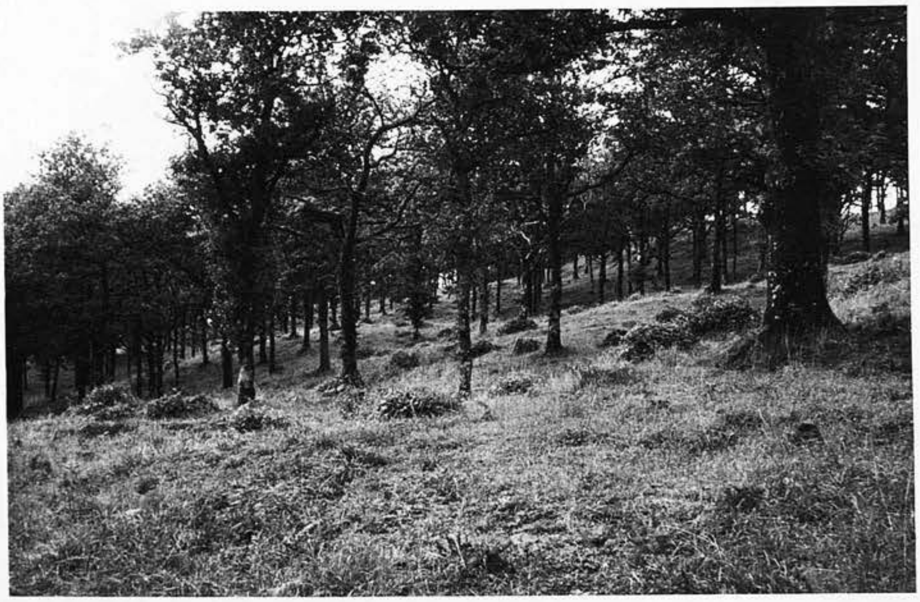


Plate 58. Oak stand heavily thinned, under which a cocksfoot/clover seeds mixture has been sown after fertilising. Taynuilt, Argyllshire.

woodland remaining on the knolls and steeper ground (Plate 32), where machinery was not able to go, are accessible to livestock for shelter.

The result of this experiment (Plates 58 to 60) is good, with both clover and cocksfoot well established. One could perhaps criticise the thinning of the oak, which appears to have been excessive even to allow the passage of machinery. Cocksfoot is a shade-tolerant grass and it seems likely that more shelter would not have harmed it, though on the other hand, clover is a strong light-demander.

The subject of seeds mixtures should receive considerable attention if grass is to be sown under a tree canopy for winter use. Shade-tolerant, winter green species are likely to be most successful for use in out-wintering projects. Armstrong (1937) lists the following species with either or both of these qualities: Creeping bent, Sweet vernal, Hungarian Brome (Bromis inermis Leyss.), Crested Dog's-tail, Cocksfoot, Common Fox-tail, Meadow fescue, Tall fescue, Red fescue (Festuca rubra L. subsp. rubra) and Rough-stalked Meadow grass. However, the main factor which will determine the ultimate choice of seeds mixtures will be the availability and/or price of the seed. Many of the above species probably cannot be obtained commercially and therefore substitutes will have to be found amongst the more common species. In addition, clover should always form part of a seeds mixture and the two varieties in common use today are Kent wild white and White New Zealand S.100.

Plate 59. Improved grazing under oak on the right compared with unimproved on left fore- and middle-ground. Taynuilt, Argyllshire.

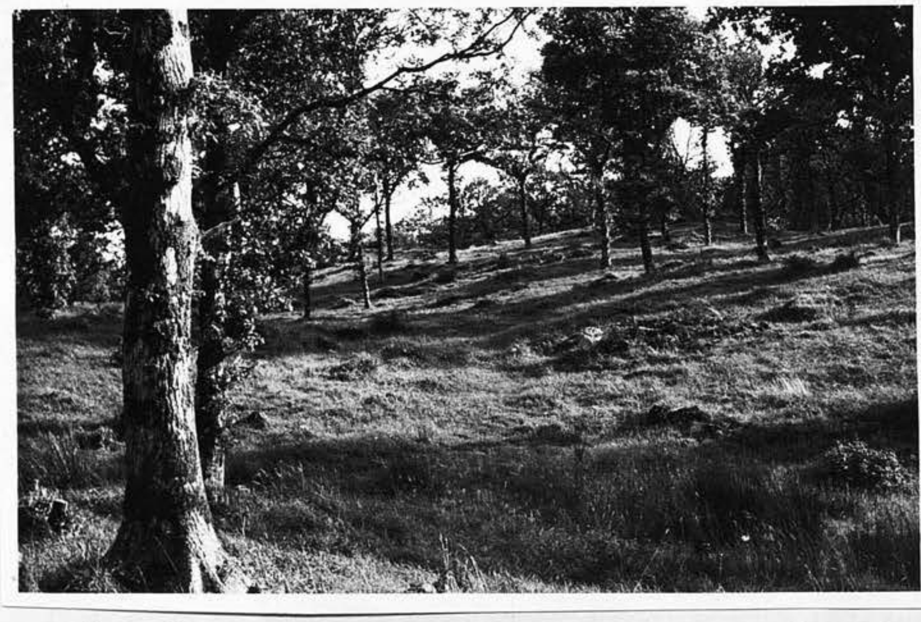


Plate 60. Improved pasture under very heavily thinned oak. Taynuilt, Argyllshire.

When considering the use of woodlands for out-wintering a suitable water supply should not be overlooked. Streams can be utilised and if inaccessible due to steep banks, these can be cut away to form gentle slopes. If the flow of water is small simple dams can be constructed by staking pieces of wood across the bed of the stream. If springs and streams are absent, ditches, containing moving water, should be made accessible to livestock by grading the banks in some places. This should help to prevent damage to the ditches. When none of these sources are available it may be possible to use polythene piping to supply a drinking trough with water from a mains tap, providing the distance involved is not excessive.

7. Grazing fees and leases

The Forestry Commission allow out-wintering in some of their forests for which a rent is charged. The range encountered is from 3/- to 5/- an acre. Sometimes the tenant is required to fence the area before use, in which case the rent is reduced to a nominal sum. There seem to be two disadvantages in this system. Firstly, a tenant could reasonably demand security of tenure if he has to erect, maintain and bear the cost of fencing. From the forestry point of view this is undesirable. Secondly, the problem will arise of determining the duration for which the nominal rent should exist (to offset initial fencing costs), after which an economic rent is to be paid. Much ill-feeling could be created if the parties failed to agree on a reasonable rent. It would seem more satisfactory if the Forestry Commission were to undertake initial fencing and all maintenance for normal wear and tear and decay (as occurs in some forests) and charge a full economic rent at the commencement of the lease. In this way any profit in the enterprise would accrue to the forester, which is reasonable since he is supplying the service.

Specimens of Forestry Commission leases show that maps are attached which indicate clearly the area let for grazing. The rent, duration of grazing period, number and type of livestock are laid down in the agreement and the tenant is held responsible for keeping his livestock within the defined area and for any damage that might occur, in which case the proprietor reserves the right to terminate the lease immediately. Sporting rights are reserved, sub-letting, camping and the lighting of fires are specifically forbidden, and the proprietor accepts no responsibility for loss or damage to the tenant's property.

8. Summary on the management of woodlands for out-wintering livestock

Whether or not a woodland is used for out-wintering seems to depend on the factors of accessibility to both man and beast, fertility and topography of the site and its proximity to the home farm. Generally any form of shelter is considered better than none at all and it is apparent that local climatic conditions will determine the requirements from a woodland for out-wintering farm stock, and this will govern the ultimate structure that forest management will be required to attain, subject to any general and/or special objects of management.

Considerable damage can be inflicted by animals on trees at any stage of growth but this can be kept at a minimum by strict control of the number, type and distribution of stock throughout the forest. Damage to woodland soils by livestock has not been fully investigated but there is evidence that it does occur. At present, therefore, it would seem wise to restrict access as much as possible and the practice of yearlong use should be discontinued.

Where out-wintering takes place simultaneously with regeneration, the latter will generally need protection, and the most practicable silvicultural systems combining out-wintering and regeneration would seem to be the Uniform and Group Selection systems, though the problem of fencing the regeneration relatively cheaply has not yet been solved. However, the new polythene and nylon nettings, which so far have proved effective against deer, hares and rabbits, would seem to offer great possibilities.

Operations to improve the quality of grazing under woodlands seem to have a limited application, though the adoption of suitable grazing régimes is desirable both for the maintenance of the vegetation and to minimise all the ill-effects of livestock on woodlands.

Grazing fees should be levied, where applicable, and leases drawn up by the forester which clearly define the terms and conditions for the use of woodlands for out-wintering farm stock.

PART 3

FIELD STUDIES
(continued)

PART 3

FIELD STUDIES

(continued)

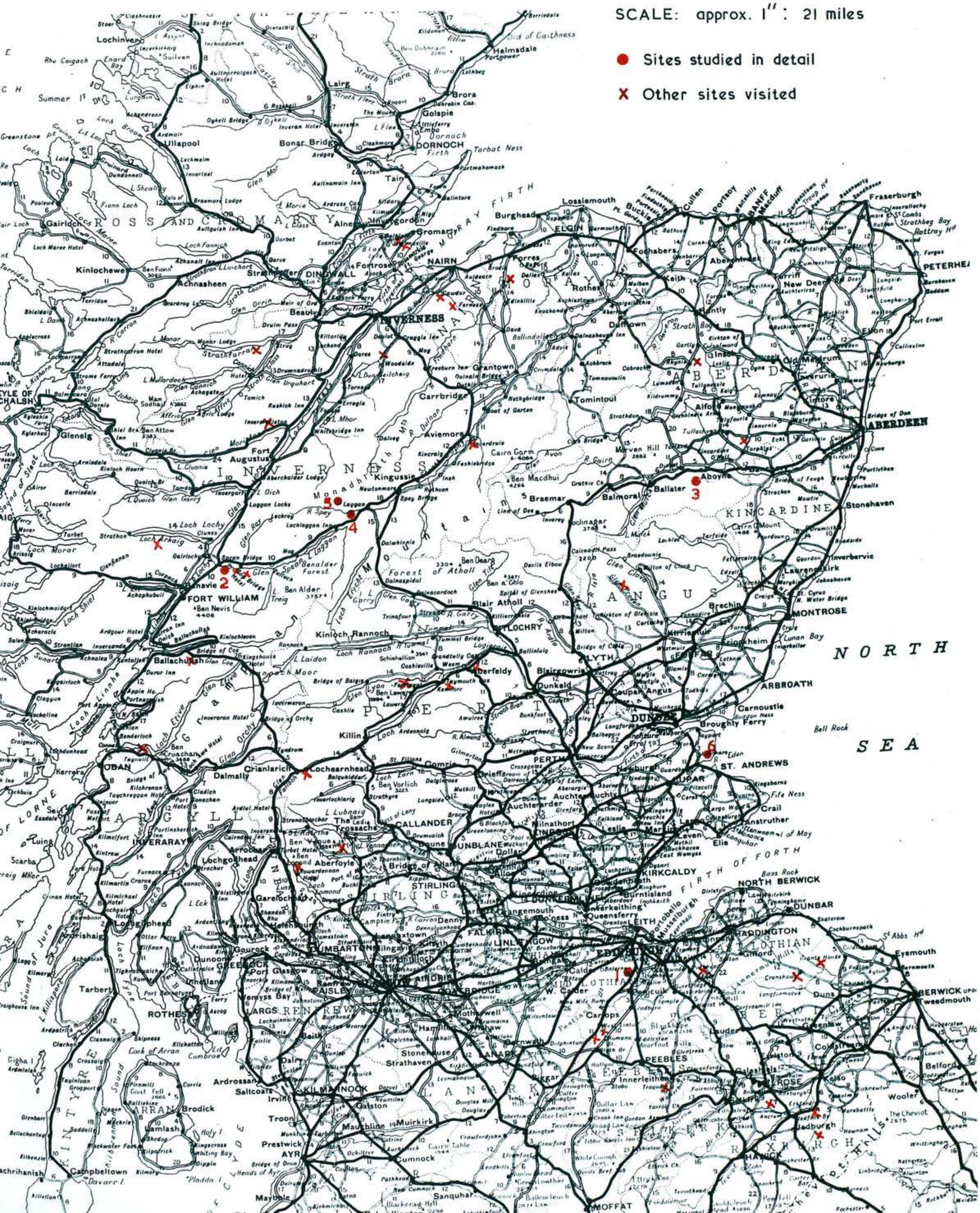
CHAPTER 11

DESCRIPTION AND TREATMENT OF SELECTED SITES

The map of Scotland on page 163 shows the approximate location of all the areas visited on the tours, preparatory to selecting the six sites for detailed study. Two factors of importance emerged from these tours. Firstly, it became clear that the use of woodlands for out-wintering farm stock is likely to be limited in application to those areas where the soil is relatively infertile and the value of agricultural land low. In East and Midlothian, and the fertile agricultural region bordering the east coast between the Firth of Forth and Moray Firth, land use is intensive and any shelter that is required usually takes the form of fenced shelterbelts, so that as little valuable agricultural land as possible is given up to forestry.

Secondly, it was generally agreed that tree shelter was most desirable for out-wintering cattle and sheep, though it is not essential for the latter, and although existing shelter is valued most highly, few farmers seem prepared to undertake regeneration of the tree cover. The reasons are mostly economic. The marginal profitability of many farming enterprises does not allow the sinking of capital into a long term investment such as the maintenance or improvement

Map of Scotland, showing approximate location of sites visited



of woodland shelter. Of necessity it has to be used for short term investments like the improvements of grazings and increasing the number of head of livestock. Therefore many woodlands which are at present being used for out-wintering are not likely to be regenerated until it is absolutely necessary. However, such a time has arrived for most of the coppice birchwoods which are generally in the region of 90 to 100 years old, though the oak, probably about the same age, can last for a considerable time yet.

The second factor seemed particularly important when selecting the areas for detailed study for there would be little point in initiating research in an area where continuity seemed doubtful.

Site 1, on Boghall Farm, Midlothian, was studied first as it was within easy reach of Edinburgh and allowed many visits to the site in order to try out working methods and perfect a system of site description. Furthermore, the site is part of the area administered by the Edinburgh Centre of Rural Economy, of which the woodlands are managed by the Department of Forestry, University of Edinburgh, for the Board of Management of the Centre, and the objects of management provide for research into forest management.

Site 2, Killiechonate oakwood, near Spean Bridge, Inverness-shire, provides an opportunity of combining forestry and grazing, as the objects of management embody the integration of forestry and agriculture. Shelter and grazing are both required for out-wintering.

Site 3, Glen Tanar birchwoods, Aberdeenshire, was selected because these woods are disappearing and the need for early regeneration is appreciated. Shelter is of prime importance for out-wintering in this region.

Site 4, pine woods, Glen Shirra, Inverness-shire, is used regularly for out-wintering cattle and sheep as it is near the home farm. The problem of forest management in this area is to provide both shelter and grazing for live-stock.

Site 5, Meall an Dhomnaich, also in Glen Shirra, is of interest due to its high elevation and the requirement of good shelter for out-wintering sheep.

Site 6, Tentsmuir Forest, Fife, was selected as it is an example of out-wintering cattle in a young coniferous forest where the commercial aspect of timber production is of prime importance and where grazing is employed as a means of reducing the high fire hazard.

SITE NO. 1

BOGHALL PLANTATION

A. SITE

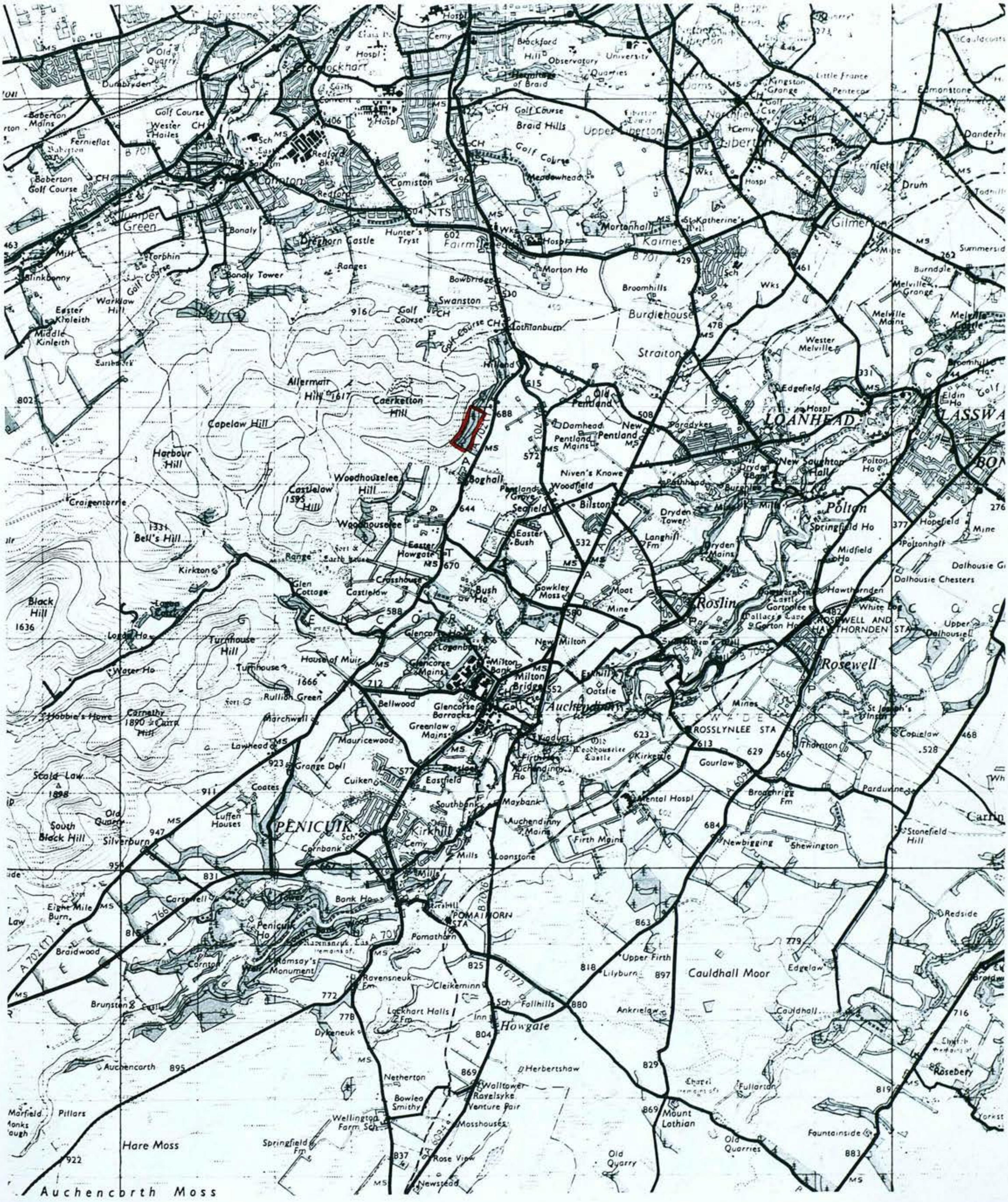
1. Location. The plantation is in the parish of Lasswade in the county of Midlothian. The 1" Ordnance Survey map reference is 653245 and the site is situated $5\frac{1}{2}$ miles south of Edinburgh on the A702 Edinburgh-Biggar road. The area is on the lower slopes of Caerketton Hill which is part of the Pentland Range. (See locality map on page 167).

2. Farm, Estate and Owner. The plantation is part of Boghall farm, owned by the University of Edinburgh and held in trust by the Edinburgh Centre of Rural Economy. Management and running of the farm is carried out by the Edinburgh School of Agriculture.

3. Boundaries and Acreage. The eastern boundary is formed by a wire-and-post fence which is in good condition and within the fence is a ditch and then a hawthorn hedge. At the south-south-east corner there is a new post-and-wire fence, separating the plantation from the Sitka spruce shelterbelt, which meets a dyke at the south-west end. The south-west boundary is indistinct, demarcated only by the line of the Sitka spruce shelterbelt which can be projected up the slope until it reaches the western boundary which is also indistinct at its southern end. The western boundary is formed by the remains of a stone dyke through which the sheep can pass freely. To the north a sturdy post-and-wire fence delimits the area from the privately-owned woodland beyond.

Locality Map for Boghall Plantation

Scale 1" = 1 Mile (Extract from Ord. Survey Sheet 62)



4. Altitude. The plantation runs more or less parallel to the contours. At the southeast corner the elevation is 750 feet, rising fairly steeply in a westerly direction to a height of 940 feet. The topmost (western) boundary remains almost constant at 925 feet, except near the middle where it reaches 950 feet.

The ground continues to rise in a westerly direction away from the plantation to the top of Caerketton Hill, at 1,568 feet. The Pentland Range recedes in a southwesterly direction and the two nearest hills are Woodhouselee (1,260 feet) and Castlelaw (1,595 feet), about a mile and two miles away respectively to the southwest.

To the east of the site the ground falls away to the Midlothian Plain and 10 miles to the southeast are the Moorfoot Hills which average 1,500 feet in height.

5. Topography. The plantation is on the lower to middle slopes on the east side of Caerketton Hill, which is the northernmost part of the Pentland Range. There is a ridge approximately in the centre of the site with natural drainage channels on either side.

The lower slopes of the area are 1 in 4 (15°), steepening to 1 in 2 (24°) towards the upper half, while in the south-southwest corner there is a small portion of the ground where the bedrock outcrops and slopes are extremely steep.

Aspects are variable, though mainly easterly. At the north end of the plantation it is east, changing to east-southeast on the north side of the central ridge and becoming southeast on the south side of this ridge and over the remainder of the site.

6. Climate. Until the middle of 1954, meteorological measurements were taken at Boghall Farm, at an elevation of 639 feet above mean sea level. Thereafter, the station was moved to Bush House, about 1 mile to the south. The meteorological data presented here is that for Boghall for the 5-year period 1949-53. In addition, wind measurement studies were carried out at this site by Dr. J.M. Caborn from October, 1953, to October, 1955, and these figures have been used in sub-section (vi).

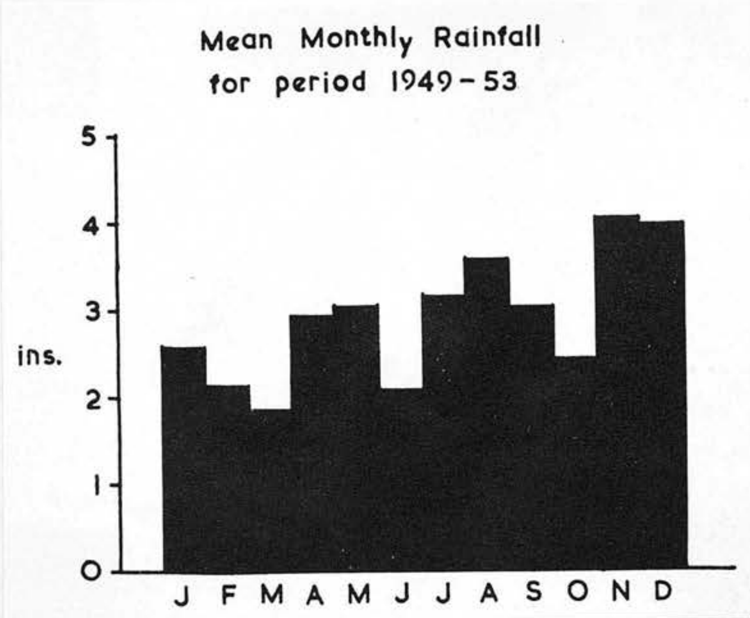
(i) Climatic zone. Boghall Plantation is in climatic sub-region B2f, but the Cld sub-region lies very close to the northeast. Data for these two regions is:

Sub-region	Mean range of temp. °F	Mean min. temp. °F	Days of frost	Sunshine. June. mean hrs/day	Year %	Growing season Rainfall ins.
B2f	42	33	50-100	5.75	28	15-20
Cld	25	36	25-50	6.25	30	<15

(ii) Rainfall.

Mean monthly rainfall for period 1949-53; inches.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
2.58	2.13	1.87	2.94	3.03	2.09	3.14	3.58	3.01	2.42	4.12	3.97	34.9



The average annual rainfall (5-year average) is 34.9 inches and is well distributed throughout the year. March is the driest month and November the wettest.

(iii) Snowfall.

Av. no. of days with snow lying at 0900 hrs. (5-year period 1949-53)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
7.6	4.8	2.8	0.2	0	0	0	0	0	0	0.4	6.0

The table shows that snow can usually be expected in December, January, February and March.

(iv) Temperature.

Average temps. for 5-year period 1949-53. ^{o}F.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly	37.0	37.6	40.4	43.7	50.2	55.7	58.7	57.7	53.5	47.8	40.7	37.9
Mean monthly minima	32.8	33.0	34.7	36.4	41.9	46.9	51.4	50.9	47.0	42.2	36.8	33.7

Temperatures reach a maximum in July and a minimum in January.

(v) Frost.

Days with ground frost. Av. for 5-year period 1949-53.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
18	16	16	11	4	0	0	0	0	6	13	19

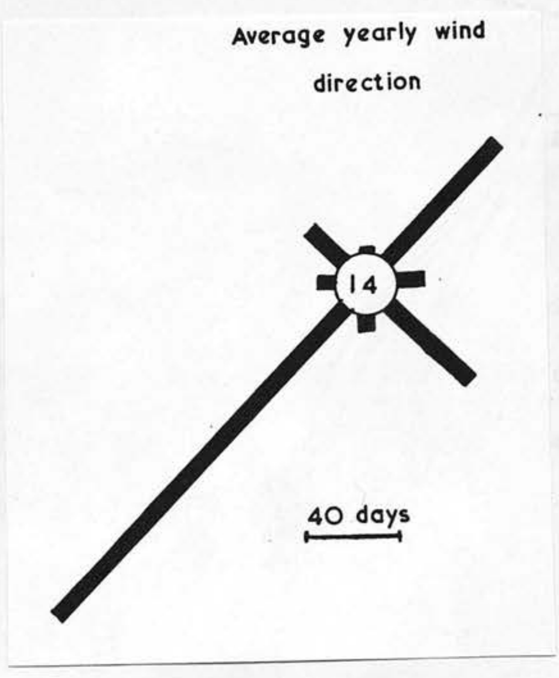
The four months June-September are usually frost free, though there is an occasional frost during June.

(vi) Wind. The effect of wind on livestock cannot be determined from velocity alone but should be considered together with the other climatic conditions, especially temperature and humidity. A strong south-west wind does not necessarily produce more rigorous conditions than a gentle north-east wind, for there is generally a lower temperature associated with the latter.

The anemometer at Boghall Farm was situated at 55° 52' 30" N, 003° 13' W, 850 feet above mean sea level and 1.5 metres above ground level. The following table is a summary of the results of wind measurements taken over a 2-year period October, 1953 to September, 1955, at this site.

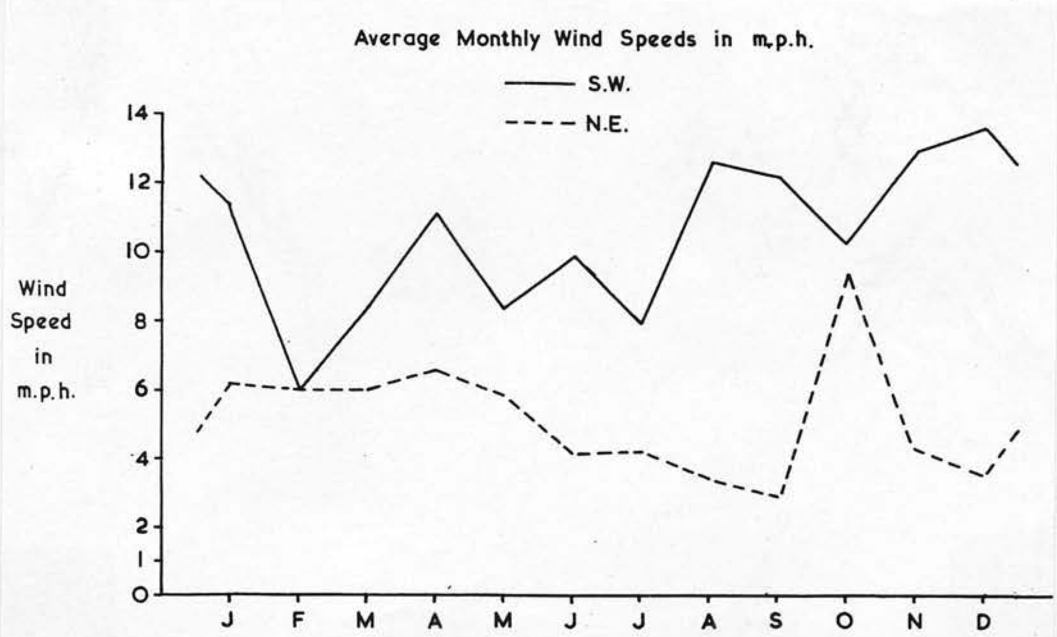
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Wind direction.	N					1						½		1½
	NE	7½	6	10½	4	9	10½	5	9½	1	2½	½	3½	69
	E	1½	2½	½	1	1	1		1	½	½	1	½	11
Av. no.	SE	4	1½	5½	6	5½	2½	1	3½	5	5	5	3	47½
of days	S		1				½	½	1	½	2	1½		7
for 2	SW	11½	9	10½	13½	8½	14	22	14	23	19½	17½	18	181
year	W	1½		1	½		½				½	2	3½	9½
period	NW	4½	3	2½	2	5	½	1				½	1½	20½
	Calm	½	1½	½	3	1	½	1½	2		1	1½	1	14
Av. Vel.	N					2.6						4.8		
by dir-	NE	6.2	6.0	6.0	6.6	5.9	4.2	4.2	3.4	2.9	9.3	4.3	3.5	
ection	E	5.2	8.1	6.1	1.4	2.6	3.9		5.8	5.7	1.6	9.6	4.1	
for 2	SE	6.5	3.6	5.0	6.2	5.9	5.7	4.8	10.7	7.6	9.3	6.3	4.9	
year	S		11.6				5.3	5.2	2.1	3.7	8.8	7.8		
period	SW	11.4	6.0	8.4	11.1	8.4	9.9	8.0	12.6	12.2	10.3	12.9	13.6	
	W	8.3		6.8	7.3		7.3				17.0	11.5	13.9	
M.P.H.	NW	9.1	8.2	9.5	3.4	7.0	7.1	1.6				4.3	6.6	
Av. no.	N													
of days	NE	½	½	1	½	½		½			½			4
with	E	½	½	½										1½
winds	SE	½			½			½	½	½	1	½		4
over	S		½											½
12 m.p.h.	SW	5½		2	6	3	5	6½	4	9½	7½	9	12½	70½
(10 knts)	W	1		½	½		½				½	1	1	5
	NW	1½	1½				½						1	4½
	Total	9½	3	4	7½	3½	6	7½	4½	10	9½	10½	14½	90

The prevailing wind is south-westerly. After this, north-easterly winds are most frequent, and like the south-east winds, occur in every month of the year.



The wind rose diagram indicates the direction and frequency of the winds in days per year, the central figure being the number of days of "calm" per year. The relative infrequency of westerly winds can be attributed to the shelter effect of the Pentland Hills and in particular to Castlelaw and Woodhouselee Hills.

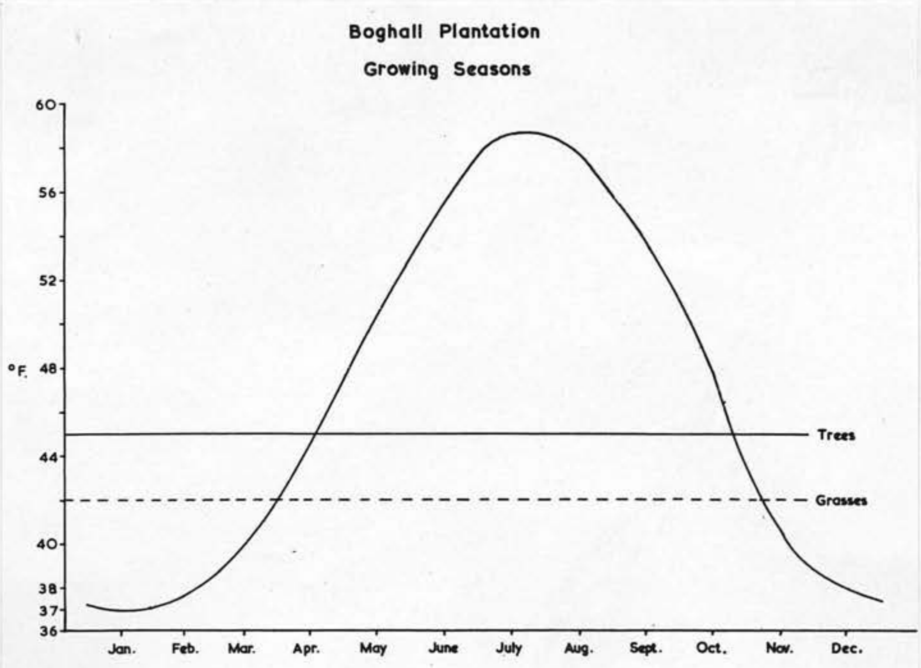
The following figure shows that there is a general increase in the speed of the prevailing wind as the year progresses. North-east winds do not fluctuate markedly during the year but there is a considerable increase in speed during October.



The lowest part of the table on page 172 shows the average number of days per month on which winds over 12 m.p.h. (10 knots) occur. This figure was selected because it was considered that wind velocities in excess of this, which on the Beaufort scale are described as "moderate", may have a significant effect on the behaviour of the grazing animal.

It is apparent that the wind is most often in excess of 12 m.p.h. when blowing from the south-west. Also of interest is the fact that although north-east winds are frequent throughout the year they rarely rise above 12 m.p.h. for any length of time. Similarly, the other notoriously cold winds, easterly and north-westerly, do not often exceed this speed.

(vii) Growing season. The length of the growing season was determined according to the method suggested by Anderson and Fairbairn (1955). Briefly, this is to plot the mean monthly temperatures as ordinates against the months (mid-months) of the year as abscissae. The following figure is



the growing season curve for the Boghall area. The length of the growing season for trees, as defined by Anderson and

Fairbairn (following Hagem), is that period of time - in number of days - which lies between the first day in spring, whose mean temperature rises to 45°F, and the first day in autumn, whose mean temperature fails to reach 45°F. The growing season of grass for measurement purposes is assumed by some agriculturists to begin when the mean monthly temperature rises to 42°F and is the figure used in this work. It can be determined from the same graph by reading off, along the abscissa, the distance between the two intersections of the 42°F line and the curve. The growing season for trees is 191 days and for grass 221 days.

7. Exposure. As the site is on the east side of the Pentlands there is good geomorphic shelter to the north-west and north, becoming poor to the north-east. The woodland on the south side of the site provides shelter from the west and south-west while the line of trees on the western boundary enhances the geomorphic shelter of Caerketton Hill.

Exposure is high from the north-east, east, south-east and south.

8. Geology.

(i) Solid. The hill grazings of Boghall Farm are underlain by andesitic lavas, with subsidiary patches of acid andesite, rhyolite and rhyolitic lavas. The arable part of the farm, in the Midlothian plain, lies on the lower carboniferous sediments.

The Plantation itself is on andesitic lava, which outcrops in several places on the steep slopes. This rock type contains silica and feldspars, of which plagioclase dominates over orthoclase and the whole breaks down into a material with a high soluble mineral content.

(ii) Drift. Ice from the Highland ice sheet moving east-south-east and that from the mountains of Galloway moving north-east met at the south-west end of the Pentland Range and the general direction became easterly (Charlesworth, 1957). Apart from the odd Highland erratics to be found on the tops of the Pentlands, the general drift material is of local origin, namely a till derived from andesitic lavas.

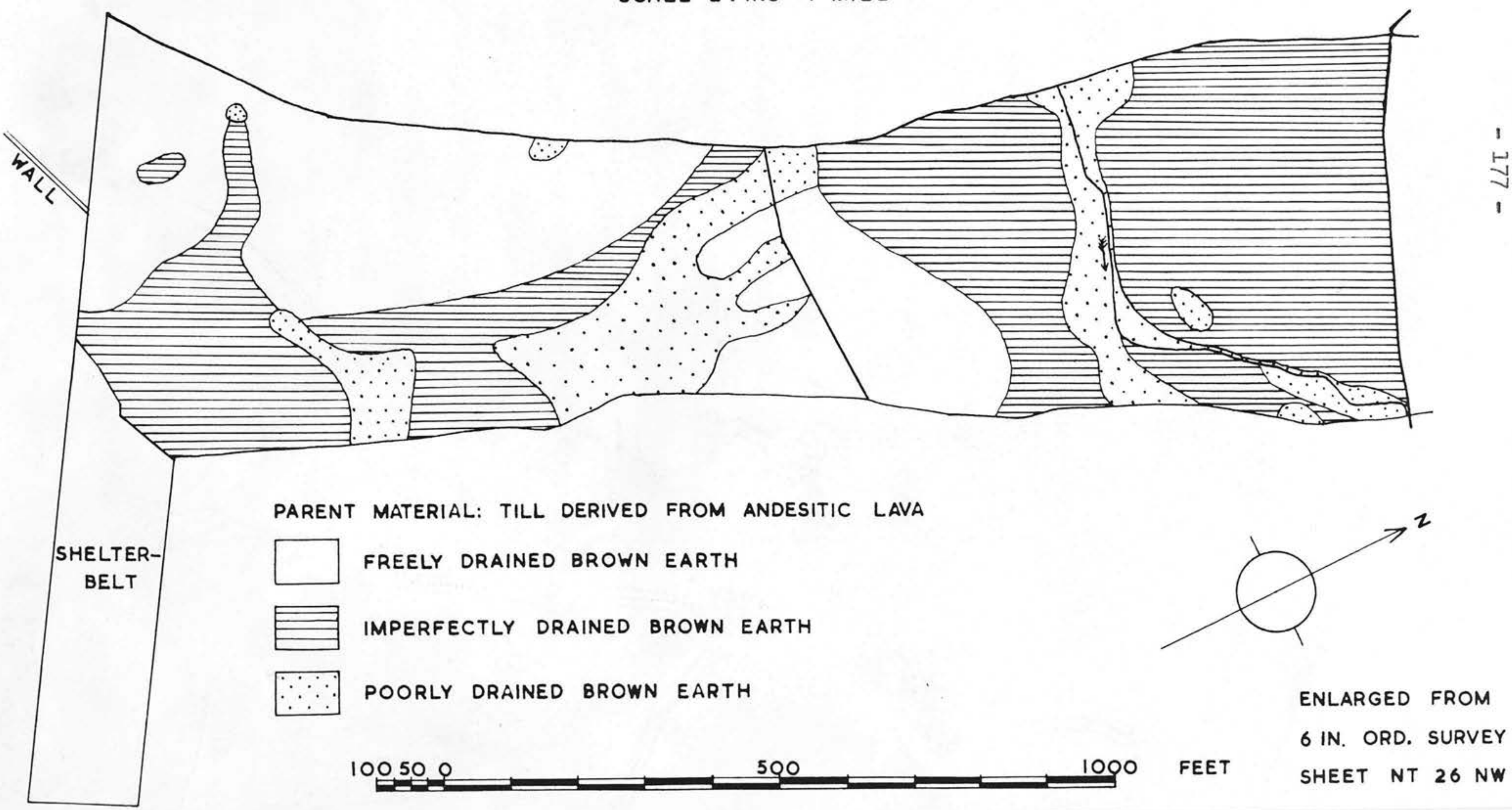
9. Soils. A fertile brown earth soil covers the whole of the area providing good conditions for tree growth. Drainage differs markedly from place to place and the soil map on page 177 has been drawn up using this criterion of drainage. The bedrock outcrops in several places and adjacent to these outcrops the soil is skeletal and very thin, while in the south-west corner there is an area of scree material which has become almost stabilised by vegetation and tree roots. Over the rest of the area soils are thin, with rock fragments and angular stones of all sizes forming the main body of the soil. The fine material binding this matrix of stones can be described as loam or clay-loam.

(a) Freely-drained brown earth. This soil type dominates those parts of the Plantation where slopes are steep.

BOGHALL PLANTATION

SOIL MAP

SCALE 24 INS = 1 MILE



Description of soil profile

Aspect: S.E.

Slope: Moderate (middle slopes)

Stand: Mixture of Scots pine, European larch, Norway spruce and Sitka spruce.

Vegetation: *Agrostis* species abundant, *Festuca* species frequent, *Oxalis acetosella* occasional.

A_{oo} Thin layer of uncompacted needles, cones and some hardwood leaves.

A_oF $\frac{1}{4}$". Thin layer of decaying grass leaves, needles, cones and hardwood leaves.

A_oH Indistinguishable.

A 6". Very dark brown in colour, with organic matter mixed with the mineral soil. Texture predominantly stony, all shapes and sizes present though very fine material is loamy. The horizon is structureless owing to the stony texture of the soil. Rooting throughout the horizon and worm activity high.

B $>$ 2 ft. The A horizon gradually merges into the B horizon, which is a light reddish-brown colour. Extremely stony; stones angular. Finer material is of sandy texture. Structureless horizon, worms absent and rooting depth to 2 feet. Drainage good.

(b) Imperfectly-drained brown earth. The most obvious feature of this soil type is the abundance of *Deschampsia caespitosa* in the vegetation. Approximately two-thirds of the Plantation has an imperfectly-drained brown earth soil.

Description of soil profile

Aspect: E to ESE

Slope: Moderate (middle slopes)

Vegetation: Agrostis species, Festuca species, Deschampsia caespitosa, all co-dominant, white clover frequent, mosses abundant.

A_{oo} $\frac{1}{4}$". Remains of vegetation, especially grasses

A_o F & H Indistinguishable.

A 6". Dark brown colour, clay-loam texture, easily kneaded between fingers. Large crumb structure, root penetration throughout horizon and worms abundant.

B 2 ft. Light red-brown colour; texture predominantly gravelly and stony. Structure large and blocky. Root penetration to 6" in this horizon, making 1 foot altogether. At 18" gleying occurs. Visible fauna absent from this horizon.

(c) Poorly drained brown earth. This soil type is confined to flush areas and ground adjacent to the burn in the northern half of the site.

Description of soil profile

Aspect: SSE

Slope: Moderate (middle slopes).

Vegetation: Hard, soft and compact rushes, Deschampsia caespitosa all co-dominant, with Carduus species, Ranunculus species, forget-me-not, Rough- and Smooth-stalked meadow grasses, Agrostis species, Crested Dogstail, Sweet Vernal and mosses frequent.

A_{oo} — $\frac{1}{2}$", consisting of the remains of much of the vegetation mentioned above.

A_o F & H — Indistinguishable.

A — 8". Dark brown colour; blocky structure; heavy gravelly-clay texture. Worms present.

Bg — 8". Throughout the B horizon gleying occurs. General colour light brown. Blocky structure with gravelly-clay texture. Visible fauna absent. Roots penetrate 4" into this horizon. Water table occurs 16" from the surface of the soil. The soil is very hard and stony, the stones being tightly bound together with clay, sand and gravel.

10. Drainage. To the north of the central ridge there is a burn which drains away in a north-easterly direction. On the south of this ridge is a shallow depression which is poorly drained due to continual flushing from springs and a lack of any drainage channel.

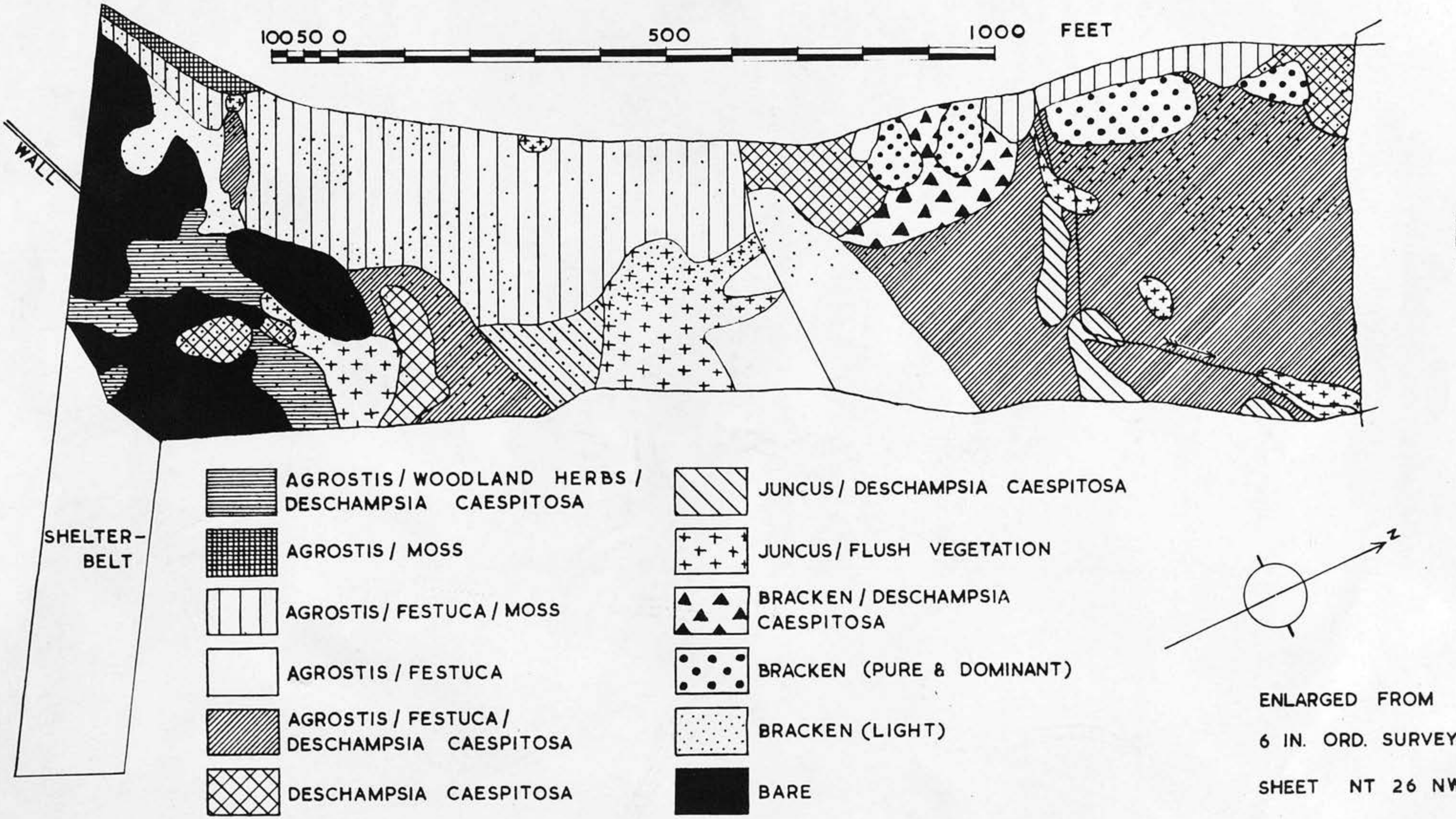
Artificial drainage will be needed in the poorly drained areas and should aim at removing only the free surface moisture.

11. Vegetation. The area is mainly covered by Agrostis/Festuca vegetation except for the woodland at the southern end which is a grass herb community. The vegetation types

BOGHALL PLANTATION

VEGETATION MAP

SCALE 24 INS = 1 MILE



ENLARGED FROM

6 IN. ORD. SURVEY

SHEET NT 26 NW

indicated on the map on page 181 contain the following plant species:

(1) Agrostis/Woodland herbs/D. caespitosa.

Common bent (Agrostis tenuis Sibth.) dominant and abundant (d & a).
- A. canina L., d & a.
Tufted Hair-grass (Deschampsia caespitosa (L.) Beauv.) very frequent (vf).
Red fescue (Festuca rubra L.) frequent (f).
Sheep's fescue (F. ovina L.) f.
Yorkshire fog (Holcus lanatus L.) f.
Creeping soft-grass (H. mollis L.) f.
Annual meadow-grass (Poa annua L.) f.
Rough-stalked meadow-grass (P. trivialis L.) f.
Smooth-stalked meadow-grass (P. pratensis L.) f.

Foxglove (Digitalis purpurea L.) locally frequent (lf).
Stinging nettle (Urtica dioica L.) lf.
Violet (Viola species) lf.
Wood sorrel (Oxalis acetosella L.) lf.
Lady's smock (Cardamine pratensis L.) lf.
Self-heal (Prunella vulgaris L.) lf.
Bugle (Ajuga reptans L.) lf.
Barren strawberry (Potentilla sterilis (L.) Garcke)lf.
Forget-me-not (Myosotis species) lf.
Ragged robin (Lychnis flos-cuculi L.) lf.
Common speedwell (Veronica officinalis L.) lf.
Germander speedwell (V. chamaedrys L.) lf.
Heath milkwort (Polygola serpyllifolia Hose) lf.
Crosswort (Galium cruciata (L.) Scop.) lf.
Heath bedstraw (G. hercynicum Weigel) lf.
Lady's bedstraw (G. verum L.) lf.
Yellow pimpernel (Lysimachia nemorum L.) lf.
Water avens (Geum rivale L.) lf.
Raspberry (Rubus idaeus L.) lf.

Rhytidiadelphus squarrosus (Hedw.) Warnst., d & a.
Mnium species, lf.

(2) Agrostis/Moss.

Agrostis species, d & a.
Rhytidiadelphus squarrosus, co-dominant (c-d)
Rough-stalked meadow-grass, f.
Sweet vernal (Anthoxanthum odoratum L.) f.

(3) Agrostis/Festuca/Moss.

Agrostis species, c-d, abundant (a).
Festuca species, c-d, a.
Rhytidiadelphus squarrosus, c-d, a.

Sweet vernal, f.
Crested Dog's-tail (Cynosurus cristatus L.) f.
Rough-stalked meadow-grass, occasional (o).
Smooth-stalked meadow-grass, o.

Barren strawberry, locally abundant (la).

(4) Agrostis/Festuca.

Agrostis species, c-d, a.
Festuca species, c-d, a.
Sweet vernal, o.

Heath bedstraw, o.

Rhytidiadelphus squarrosus, lf.
Hypnum cupressiforme Hedw., lf.

(5) Agrostis/Festuca/D. caespitosa

Agrostis species, c-d, a.
Festuca species, c-d, a.
D. caespitosa, sub-dominant (s-d), a.
Sweet vernal, a.
Crested Dog's-tail, f.
Mat-grass (Nardus stricta L.), o.

Heath bedstraw, a.
White clover (Trifolium repens L.), a.
Barren strawberry, f.
Tormentil (Potentilla erecta (L.) Räusch.) f.

Rhytidiadelphus squarrosus, a.
Pleurozium schreberi (Brid.) Mitt., f.
Dicranum scottianum Turn., o.

(6) D. caespitosa.

D. caespitosa, d & a.

(7) Juncus/D. caespitosa.

Soft rush (Juncus effusus L.), f.
Hard rush (J. inflexus L.), f.
Compact rush (J. conglomeratus L.), f.

D. caespitosa, a.

(8) Juncus/Flush vegetation.

Soft rush, a.
Hard rush, f.
Compact rush, f.
Jointed rush (Juncus articulatus L.), lf.
Heath rush (J. squarrosus L.), o.

Agrostis species, f.
Sweet vernal, f.
Meadow grass, f.
Crested Dog's-tail, f.
Yorkshire fog, f.
Creeping soft-grass, f.

Ranunculus species, very frequent (vf).
Lady's bedstraw, f.
Carduus species, o.
Myosotis species, o.
Viola species, o.
Ragged robin, o.
Lady's smock, o.
Yellow pimpernel, o.
Primrose (Prunella vulgaris Hudson), o.
Goosegrass (Galium aparine L.), o.

Horsetails (Equisetum species), a.

Hylocomium splendens (Hedw.) B & S, vf.

(9) Bracken/D. caespitosa.

Bracken (Pteridium aquilinum (L.) Kuhn), c-d, a.
D. caespitosa, c-d, a.
Foxglove, f.
Stinging nettle, f.

Bracken, (pure and dominant), is confined to a small area in the north-west of the site though a light bracken cover is found over much of the site.

Vegetation Type	Acreage	Acreage as % of total area
1. Agrostis/Woodland herbs/D.caespitosa	1.0	4½
2. Agrostis/Moss	0.2	1
3. Agrostis/Festuca/Moss	1.8	8
4. Agrostis/Festuca	4.6	22
5. Agrostis/Festuca/D. caespitosa	6.1	28
6. D. caespitosa	1.2	6½
7. Juncus/D. caespitosa	0.9	4
8. Juncus/Flush vegetation	1.8	8½
9. Bracken/D. caespitosa	0.5	2
10. Bracken (pure and dominant)	1.0	4½
11. Bare	2.3	11

12. Harmful influences. Grazing is the most serious influence on the woodland. No natural regeneration sur-

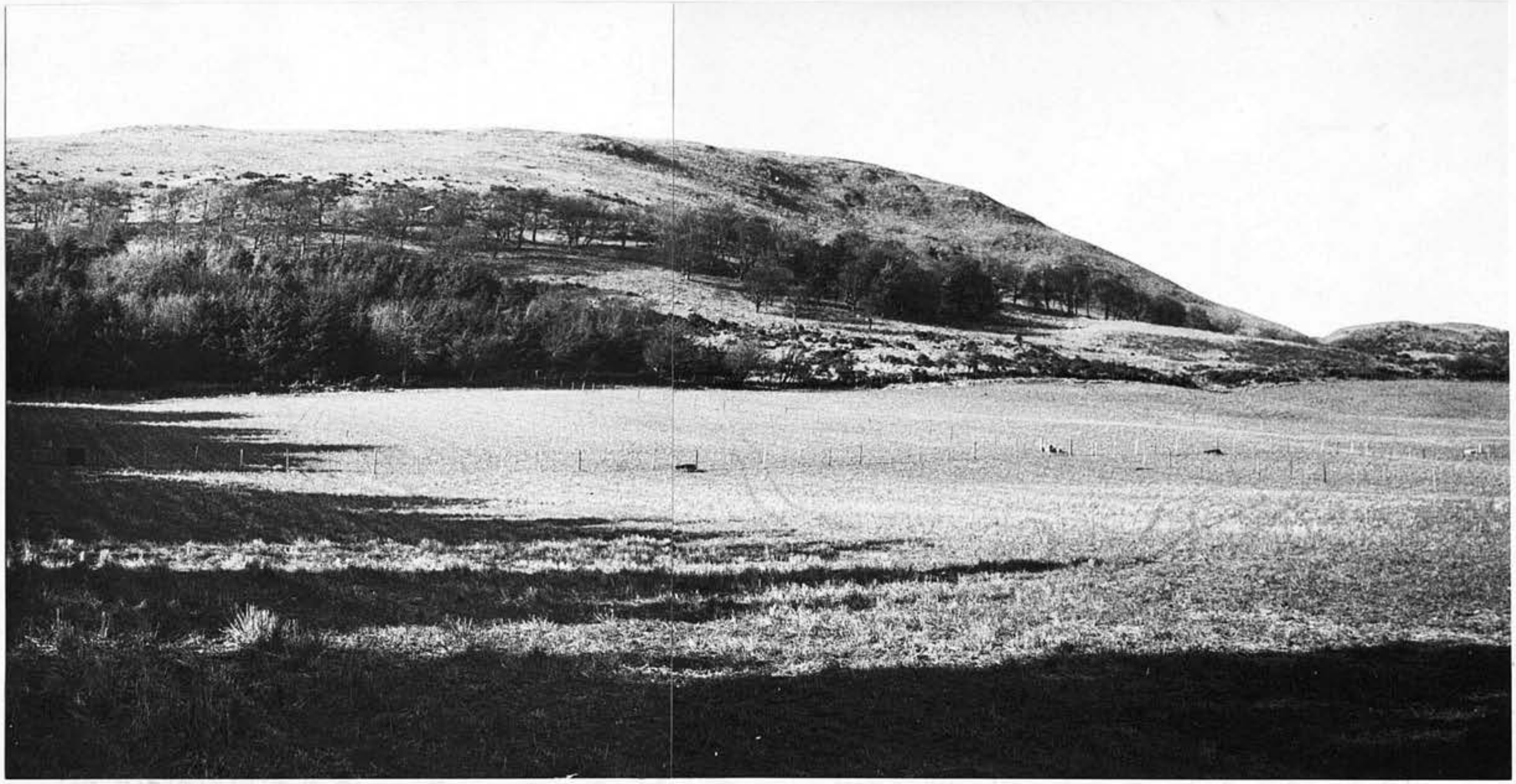


Plate 61. Southern half of Boghall Plantation, looking west.

vives for more than a year.

Exposure is high and crown deformation has taken place in larch. Windblow has occurred in the Sitka spruce shelterbelt to the south-south-east of the site.

13. Use of surrounding land. On the west (uphill) side of Boghall Plantation the land is rough grazing. To the east and below the Plantation the land is arable and this extends into the Plain of Midlothian. There is a residential area to the north of the site while to the south arable farming again assumes the major land use.

14. Communications. There are no paths or tracks into the area. However, access can easily be obtained from the fields to the south-east or along the slope from Boghall Glen. The A 702 Edinburgh-Biggar road runs past the site to the south-east. The public use the site for recreation at all times of the year.

B. STAND

1. Species (Plates 61 & 62). To the south-west there is a U-shaped block of Sitka spruce, with a spruce/sycamore coppice mixture at the base of the "U" (Plate 29). In the centre of the "U" there are mixed conifers; European larch, Scots pine and Norway spruce (Plate 63). On the north-east side of the spruce block there is a birch/Sitka spruce mixture, becoming pure birch towards the edge of the stand. Pure sycamore (Plate 64) dominates the higher ground. Groups of other hardwood species occur; Elm (European white elm,

Plate 62. Northern half of Boghall Plantation, looking west.

Plate 63. Mixed conifer stand, under which there is a moderate grass sward.

Ulmus laevis Pallas.,) beech and ash, with the occasional oak, alder and hazel.

Gorse covers much of the open ground.

2. Structure. The woodland is entirely single-storied and even-aged within each species.

3. Height. The sycamore high forest averages 65 feet top height, the coppice 20 feet, with a timber height for both of 13 feet. The average top height for the Sitka spruce is 42 feet (height to first branches varies from 0 to 4 feet) and for the mixed conifers 38 feet. Top height for birch is 10 to 15 feet and the remaining hardwoods are very variable but always in excess of 30 feet top height.

4. Canopy. Sitka spruce has a 100% canopy, though there are a few small clearings in the stand. Sycamore has a dense canopy, 90%, as has the Sitka spruce/sycamore coppice area. The birch is still fairly dense, having a 70% canopy, while the mixed conifer area is least dense of all with 60%.

The canopy per cent cannot be assessed for the tree cover along the western boundary as this is just one row of trees (Plate 62).

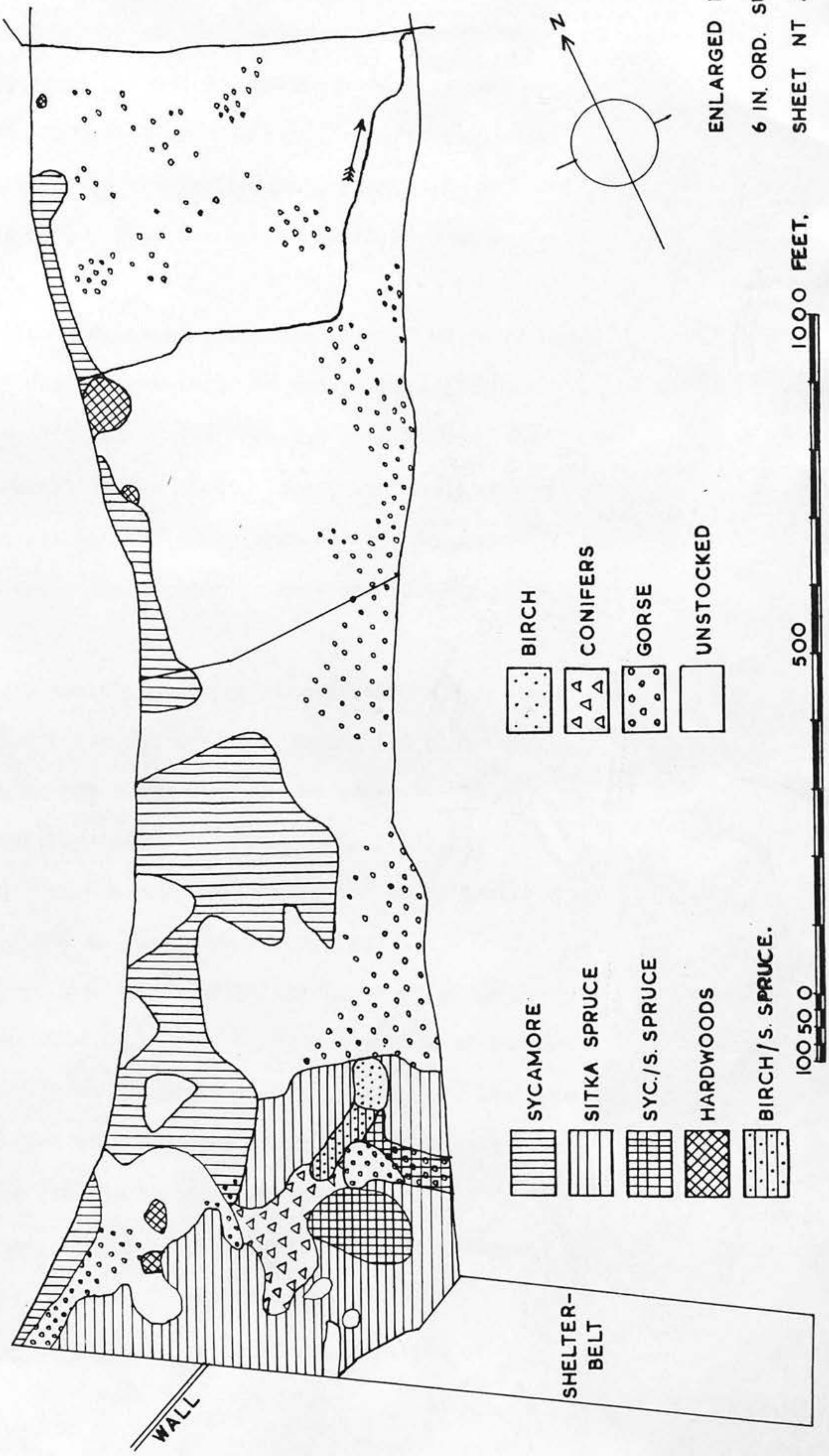
5. Origin, age and development stage. The sycamore in mixture with the Sitka spruce is of coppice origin, probably dating from the time of planting of the spruce, i.e. about 40 years old. It is in the medium pole stage. The remaining area of this species is high forest, about 100 years of age, and in the medium to large timber stage.

Plate 64. Sycamore stand.

BOGHALL PLANTATION

STAND MAP

SCALE 24 INS = 1 MILE



The birch is partly of coppice and partly seedling origin, both 30 years old and in the small pole stage.

The various hardwoods and the mixed conifers are probably the remains of the original Boghall Plantation and are about 100 years old. They are in the small to medium timber stage.

The main block of Sitka spruce was planted 40 years ago in 1922 and has reached the small to medium pole stage.

6. Form and condition. The form and condition of the sycamore high forest is not good. Heavy branching occurs at a low height and many of these branches are decaying. Generally, the trees are decadent; many are already stag-headed.

The birch is healthy although it needs thinning.

Of the other hardwoods oak, elm, beech and alder are healthy but ash is not doing well. The stems are badly cankered and the trees stunted.

The spruce/sycamore coppice is thriving well, though a thinning is required in the sycamore coppice.

A thinning is also required in the large Sitka spruce block, which has been neglected. There has been no brashing and little natural pruning has taken place. While this species is thriving at present, it is being attacked by aphis and needle cast is apparent in some trees.

In the mixed conifer block most trees are mis-shapen and of poor form, though all are thriving.

7. Natural regeneration. Natural regeneration of

sycamore and elm occurs abundantly but it is destroyed within a year by grazing. Some hawthorn regeneration has become established but is being kept in check by browsing.

8. Stocking and volume. Volumes have been calculated only for the major species. The majority of hardwoods, apart from sycamore, are so deformed that even an approximate volume would probably be misleading.

Species	No./acre	Vol./acre H.ft.O.B.	Stand type	Remarks
Sycamore high forest Ash Elm Beech Other hardwoods Spruce Other conifers	71 5 3 3 7 4 1	533	Sycamore plus mixed hardwoods	100% enumeration carried out.
Sitka spruce	1440	2240	Pure Sitka spruce	Calculation by relascope and sample plot.
Scots pine E. larch N. spruce	47 20 42	208 188 133	Mixed conifers	100% enumeration carried out.
S. spruce Syc. coppice	270 230	700 175	S. spruce/ sycamore coppice	Data from sample plot.
S. spruce Birch	60 110	- 52	Spruce/ birch	100% enumeration carried out.
Birch	270	84	Pure birch	100% enumeration carried out.

9. Acreage.

(i) Total: 21.4 acres
(ii) Present productive: 6.9 acres

Sycamore	3.3	"
Sitka spruce	2.2	"
Syc./S. spruce	0.5	"
Mixed conifers	0.4	"
Hardwoods	0.3	"
Birch/S. spruce	0.1	"
Birch	0.1	"

(iii) Present unproductive: 14.5 acres
(iv) Potentially productive 21.4 acres

C. PAST AND PRESENT TREATMENT

1. Forestry.

Boghall Plantation was probably established about 1860, the main species being Sycamore, Scots pine, European larch and Norway spruce. During the 1914-18 war most of the Plantation was felled leaving it in its present state. In 1922 the Sitka spruce shelterbelt to the south was planted, including the Sitka spruce block in the working area. Since that date the spruce appear to have had one thinning, though no brashing has taken place. There does not seem to have been any other treatment on the site.

2. Grazing.

(i) Season of use. The area is open to grazing throughout the year.

(ii) Type of stock. A heft of 103 blackface ewes have access to the area during the whole year. This figure rises during the spring and early summer after lambing. In addition, 9 Galloway cows are agisted to the hill in summer (May) and leave the hill in late November, during which time they also have access to the woodland.

(iii) Stocking. Sheep - 2.0 acres per ewe
Cattle - 39 acres per beast.

(iv) Condition of vegetation. The vegetation is in moderate condition. There is a high content of mosses in all vegetation types. Under the tree cover in the south-west of the area the grass lacks density.

The vegetation map shows that Deschampsia caespitosa occurs over a large part of the area (45%) and as it seems to be unpalatable to sheep for most of the year this ground is of limited value for grazing. The number of cattle present during the summer are insufficient to keep this species from becoming very coarse, though in the shade of the woodland the plant has finer leaves and is grazed more closely. Bracken also occurs over 40% of the area and with an increased stocking of cattle during the summer this figure may be reduced.

A total of 24% of the area bears vegetation that is of little value for grazing by sheep.

(v) Water supply. Livestock can obtain their water from the burn. There are also several springs.

(vi) Damage to the stand. Generally livestock have prevented natural regeneration from becoming established or where it has done so it is now in check due to browsing. There is occasional damage to tree roots along sheep tracks.

D. POSSIBLE FUTURE TREATMENT

1. Controlling factors.

(i) Objects of management. The woodlands of the

Edinburgh Centre of Rural Economy, of which the Plantation is a part, are managed by the Forestry Department, University of Edinburgh. The objects of management laid down by Anderson in 1953 are:

(1) to provide in the fullest possible manner protection for the lands and buildings of the Centre from harmful climatic conditions;

(2) to provide, primarily for consumption on the property, the maximum amount of the most useful forest produce, in perpetuity;

(3) to furnish important elements in the amenity of the property for both ornamental and recreational purposes, and

(4) to provide opportunity for research, experiment and education in the management and economics of woodlands designed to fulfil the first three functions.

Possible future treatment of this site will be limited by these considerations. The third object, that of amenity, should receive some attention for the Plantation is conspicuous from considerable distances.

(ii) Requirements for out-wintering. Both shelter and grazing are desirable in this area. Exposure is high to the north-east, through east, to south-west and protection from south-west and north-east winds is necessary. Snow is not a significant problem.

(iii) Site. The site is near the Home farm and is valuable for winter shelter and grazing. The area, however, is small (21.4 acres) and it will not be practicable to divide the site up in order to institute a rotational grazing régime as this would preclude the use of much of the grazing area. Similarly, regeneration operations should be confined at first to those areas of the hill which bear the least valuable vegetation types so that as little good grazing land as possible is withdrawn from use.

2. Sylvo-pastoral objective.

The site is designated for forestry and will ultimately be fully-stocked with trees. However, as the objects of management include both the provision of shelter and experimentation, it is suggested that the area should not be closed entirely for grazing but that the long term objective should be to use the site during the winter months only.

The tree cover is unevenly distributed at present, being concentrated in the southern half, while the northern half has only a belt of hardwoods along the western boundary. It is desirable, therefore, to initiate regeneration in the northern half.

As the site is small any reduction in grazing area would be serious. To keep the reduction to a minimum it is recommended that a method of group regeneration be adopted and that not more than 5 acres should be enclosed for regeneration at one time. This will reduce the effective grazing area from 21 to 16 acres. Groups should be as large as possible so that good shelter, and a woodland microclimate, can be established as quickly as possible. Fencing costs would also be lower with this method than with the current size of 1/10th acre groups which are being used in other parts of the management plan area.

The sylvo-pastoral objective for this area is one of a mixed hardwood/conifer plantation, with conifers and dense-canopied hardwoods occupying the wet sites and the vegetation types of low grazing value, and light-canopied hardwoods and conifers being planted on the better grazing land.

The effect of planting trees with dense canopies on the poorest vegetation types (D. caespitosa, Juncus/D. caespitosa, Bracken/D. caespitosa and pure bracken) would be to suppress this vegetation which, by careful manipulation of the future tree cover, could be replaced by more valuable grasses. The dense tree cover would also provide good shelter for livestock.

To achieve this object, choice of species, both from a silvicultural and agricultural point of view, should include sycamore, oak, elm, lime and beech on the freely and imperfectly drained soils. Silviculturally, ash, aspen and common alder are suitable species for the poorly drained soils but experience suggests that the canopy of ash (and probably aspen) is not dense enough to suppress the vegetation under it and therefore Norway spruce should be substituted. This would have the added advantage of increasing the efficiency of the tree cover as shelter for livestock.

On the better vegetation types (Bent/Fescue), trees with light canopies should be planted so that the vegetation is not suppressed through lack of light and/or a thick litter layer. Of the silviculturally desirable species - sycamore, oak, elm, beech, lime and birch, only birch can be used on these areas, together with suitable alternative species such as larch, ash and rowan.

In order to keep the maximum area of the better vegetation open for grazing while regeneration is in progress, it is suggested that planting should begin on the wet areas, bearing the Juncus/D. caespitosa and Juncus/Flush vegetation types, and proceed to the other poor types - D. caespitosa, Bracken/D. caespitosa and pure bracken - leaving the better areas till last, and not more than 5 acres should be enclosed at any one time. After successful establishment, regeneration areas should be re-opened to livestock and further areas enclosed until the whole site has been fully stocked.

3. Short term treatment (Next 5 years).

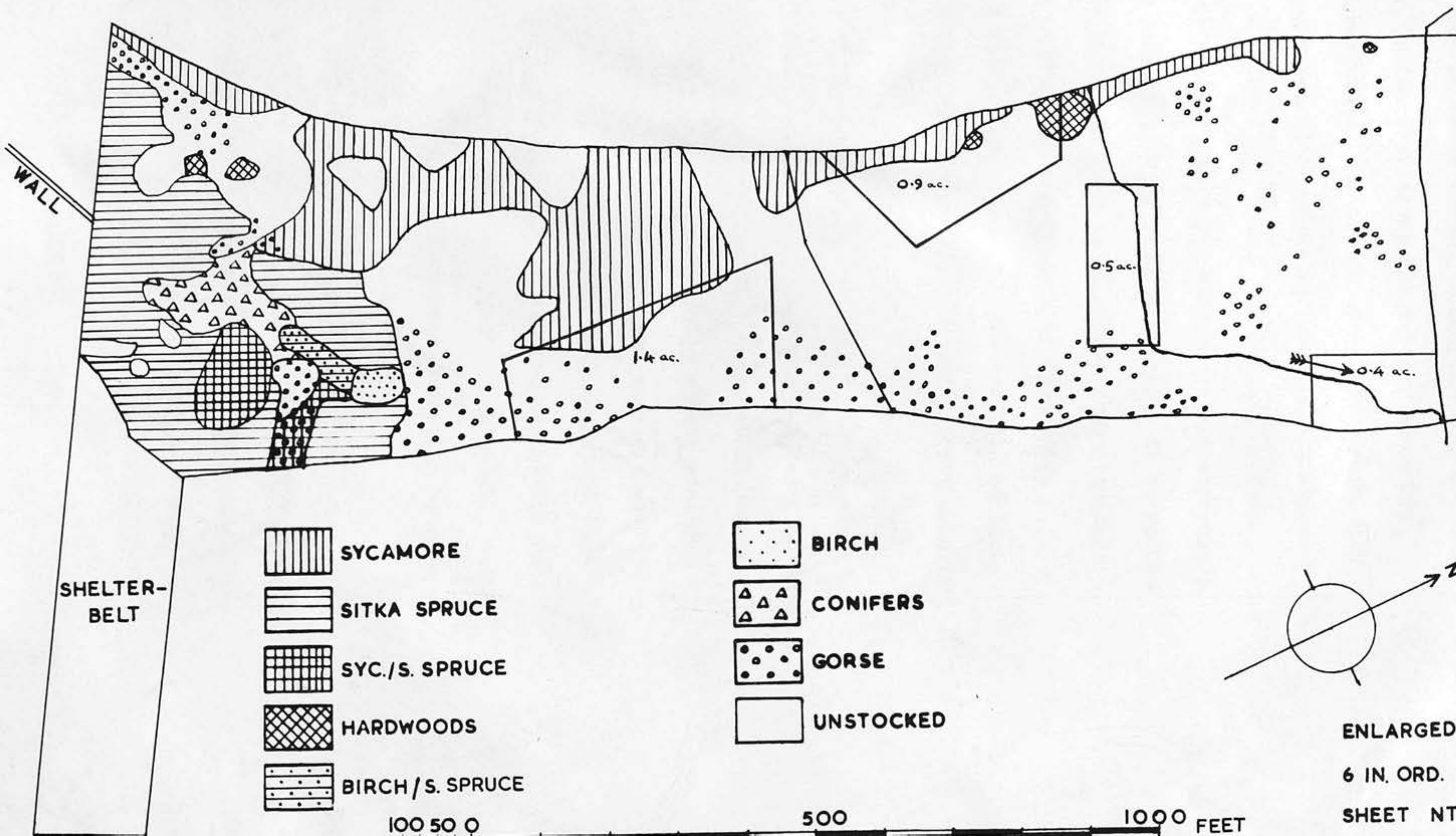
Before the wet areas are planted it would be desirable to carry out drainage, and this should be directed towards removing only the surface water. Over-drainage is a danger on this site. After drainage the areas will require fencing against cattle and sheep.

At present 2.3 acres under spruce are devoid of vegetation and therefore it is suggested that only 3 acres out of the permissable 5 be regenerated in the first instance. Possible areas for regeneration are outlined in red on the map on page 196. The total area amounts to 3.2 acres. In

BOGHALL PLANTATION

STAND MAP

SCALE 24 INS = 1 MILE



ENLARGED FROM
6 IN. ORD. SURVEY
SHEET NT 26 NW

the wet areas species could include Norway spruce, ash and common alder. On the area along the western boundary dense-canopied hardwoods such as oak, sycamore, beech, elm and lime are indicated to suppress the undesirable vegetation.

Gorse occurs over much of the area and as it suppresses all vegetation under it, it is recommended that it be reduced in area. Some should be left as it provides shelter for lambs and food when the ground is covered with snow.

Concurrent with these operations the woodland at the south-west of the Plantation should be thinned, particularly the Sitka spruce and sycamore coppice.

As much of the vegetation, especially in the northern half, seems to be under-utilised at present, resulting in an accumulation of dead grass leaves each year, it is suggested that during the first 5-year period cattle should continue to use the area during the summer, and the number should be increased. This should result in the breaking up of the large tussocks of <u>Deschampsia caespitosa</u> and reduce the rank growth of Fescues, Sweet Vernal and Crested Dog's-tail, which thereafter could be maintained in better condition by sheep.

4. <u>Long term treatment</u>.

Routine operations each year must include inspection of fences and drains, with maintenance where necessary.

At the end of the first 5-year period it is recommended that the Plantation be closed to stock during the summer. This would ensure an adequate supply of forage for winter use, as well as clean grazing land. This can be done by shepherding the livestock or fencing the area. However, it may be found that closure during the summer results in the vegetation reverting to the present state of long, rank growth, which is not liked by sheep. Under these circumstances subsequent treatment should be modified and the site stocked during the summer with cattle only.

Regeneration initiated during the first 5-year period should remain protected until it is considered out of danger from browsing (probably a minimum of 10 years will be required). When this stage has been reached, the areas can be re-opened to grazing and other sites enclosed to maintain the regeneration area at 5 acres. It is likely that the site will be completely regenerated in this way within 50 to 80 years, depending on the time taken to outgrow the danger from browsing.

SITE NO. 2

KILLIECHONATE OAKWOOD

A. SITE

1. Location. The site is in the county of Inverness and within the parish of Kilmonivaig, the 1" Ordnance Survey map reference being 230814. It is at the west end of Glen Spean, ¾ mile east-south-east of the village of Spean Bridge and on the south side of the River Spean. The nearest town is Fort William, 10 miles away to the south-west.

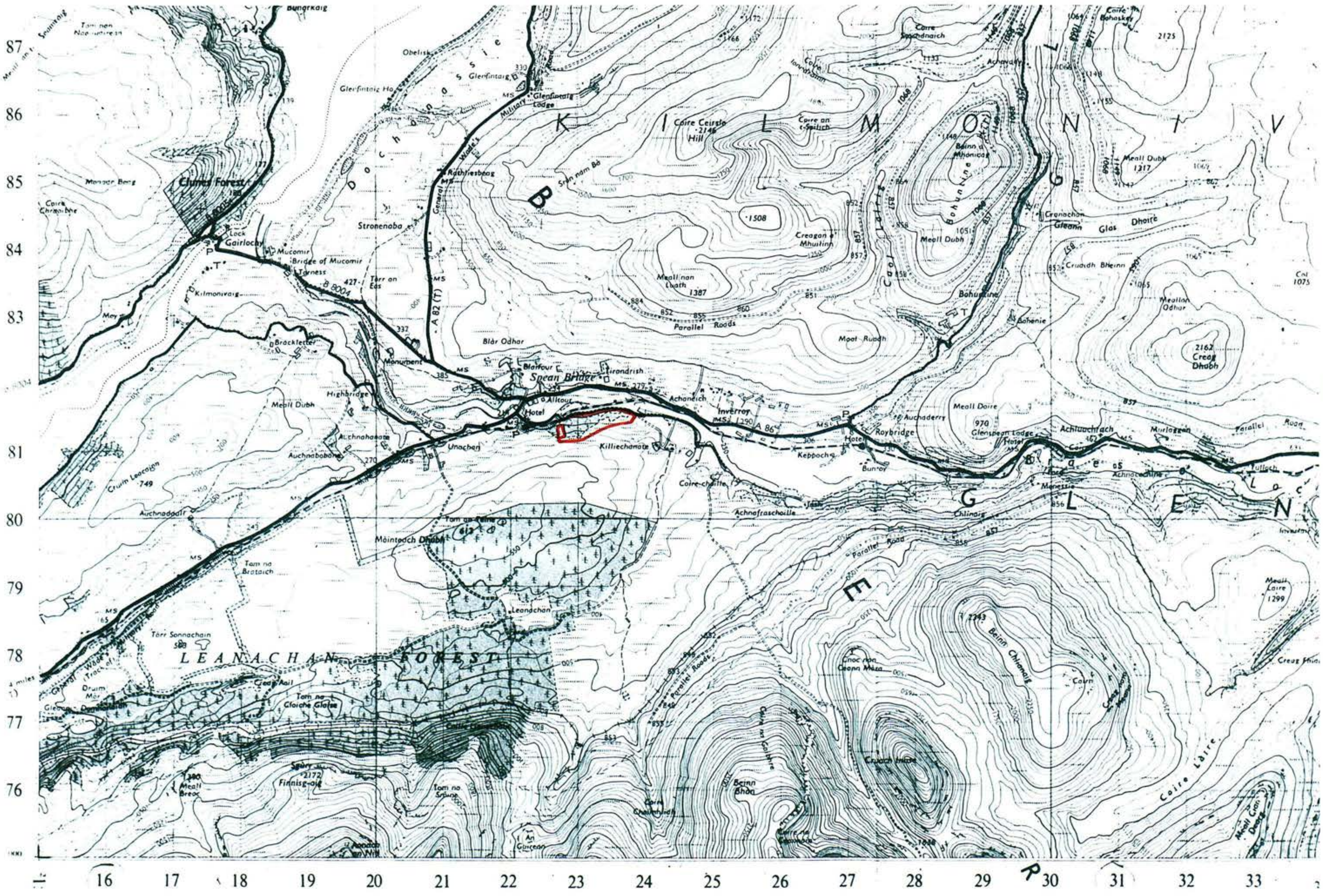
2. Estate and Owner. The oakwood is included in the area of land which forms the hirsel of Killiechonate, the whole being owned by The British Aluminium Company Limited.

3. Boundaries. All boundaries are distinct. To the north, for the most part, an unfenced, metalled road demarcates the site while to the east a dyke forms the boundary, beyond which is a grass field. A weak wire-and-post fence forms the first stretch of the southern boundary with the land beyond devoted to rough grazing. As soon as a coniferous plantation is reached, the remaining part of the boundary is formed by a strong wire-and-post fence, changing in direction slightly from time to time. A deer fence delimits the site on the west, and this continues in a northerly direction to meet a wire-and-post fence at the north-west corner, which runs along the edge of the main Fort William-Glasgow railway line, and constitutes the remaining part of the northern boundary.

A nursery in the south-west corner of the wood, surr-

Locality Map for Killiechonate oakwood

Scale 1" = 1 Mile (Extract from Ord. Survey Sheet 36)



ounded by a deer fence, is outwith the working area.

4. Altitude. The range of altitude over the site is small. The highest ground in the south-west corner is around the 400 foot contour, with the land falling away to the north and east to a minimum of 225 feet.

Reference to the accompanying locality map will show that the hills to the south-west, south and south-east are into the 2000-3000 foot range, reaching a maximum of 4,406 feet at Ben Nevis, just under 8 miles away to the south-west. Those to the north-west, north and north-east of the area are slightly lower, being in the region of 1500-2000 feet.

5. Topography. The most significant feature of the general topography in this area is the effect of glaciation; steep-sided mountains, deep corries and U-shaped valleys. Morainic mounds make up the low level topography, which in turn have been modified by fluvio-glacial and glacio-lacustrine action. There are parallel roads on the surrounding hill sides indicating that a vast lake covered the low ground during some part of the last Ice Age.

The oakwood lies on the lower slopes of the morainic outfall to the north of the Ben Nevis mountain range. Elevation increases both from north to south and north-east to south-west. At the east, the ground slopes gently and uniformly upwards towards the south and west, the slope increasing until it reaches a maximum of 1 in 4 (14^{o}) at about one third of the length of the area from the eastern

Plate 65. The ridge and hollow type of topography.

boundary. Although the general slope remains constant thereafter the configuration of the ground changes due to the presence of steep sided hillocks and ridges, with burns running through shallow gulleys (Plate 65). This sudden change in topography can probably be attributed to glacial action, for Charlesworth (1957) mentions that an ice-dam spanned the River Spean at Tivandrish (Tirandrish?) to form a lake at 420 feet, the waters overflowing by the col at the south-west corner of Loch Lianachan. This suggests that the lake curved round into the valley of the Cour and therefore the eastern third of the oakwood was probably part of the lake, further evidence being that the point immediately opposite Tirandrish more or less coincides with the end of the eastern third of the site. The ice-dam must inevitably have contained morainic debris, which, after deposition, was eroded to give the present irregular configuration to the remaining two-thirds of the oakwood.

The aspect of the site varies only slightly, the eastern third being north-north-east, the middle third due north and the western third north-north-west.

6. Climate. (i) Climatic zone. The oakwood lies just in climatic sub-region B4c while sub-region B3a is adjacent to the north, the boundary being the River Spean. It seems likely that the climate will be intermediate between these two sub-regions.

The climatic data for these two sub-regions is:

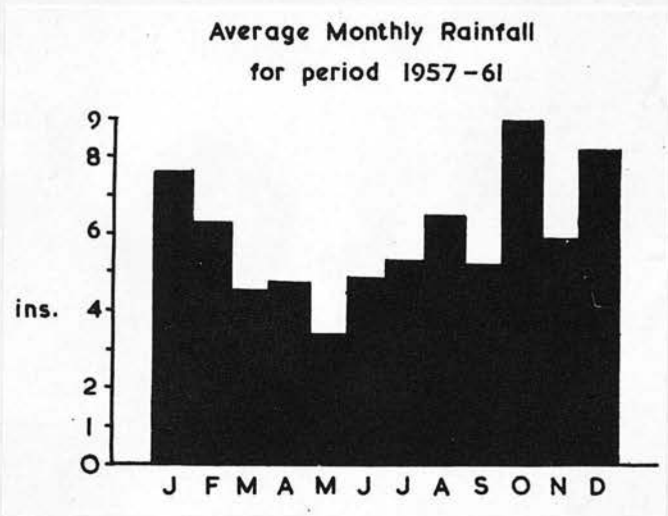
Sub-region	Mean range of temp. °F.	Mean min. temp. °F.	Days of frost	SUNSHINE		Growing season rainfall ins.
				June mean hrs./day.	Year %	
B 3a	25	34.5	50-100	5.0-6.5	23	20-30
B4c	20	36	50-100	6.0	25	>30

Growing season rainfall is more than 30 inches with a growing season of 191 to 195 days.

(ii) Rainfall. (Recorded at Killiechonate nursery).

Mean monthly rainfall for period 1957-61; inches.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
7.6	6.3	4.46	4.7	3.4	4.85	5.25	6.5	5.2	8.95	5.85	8.15	71.2



These figures show that May is the driest, and October the wettest, month of the year.

(iii) Snowfall. No figures are available for the number of days of snow occurring in this area during the year but the local inhabitants say that there are very few days of snow and that if it does fall it usually thaws quickly.

(iv) Temperature. (Recorded at Killiechonate nursery)

Average temps. for 5-year period 1957-61. °F.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly	30.0	32.5	41.6	44.2	50.6	56.0	55.2	57.2	52.0	46.2	40.7	32.8
Mean monthly minima	9.6	14.5	25.2	24.8	29.2	34.8	35.2	34.4	32.0	29.2	25.0	15.6

Lowest mean monthly temperatures occur in January and the highest in August.

(v) Frost. No accurate information is available for this area as to the number of days of frost per month or per year, but from the data for this climatic sub-region, 50 to 100 days of frost would be expected per year.

(vi) Wind. Wind data is available for the Fort William area but it has been considered unwise to use this as great variation in meteorological conditions takes place in this area due to the topography.

However, from the experience of local people it appears that the prevailing wind is west-south-west. Strong winds are infrequent but during the spring dry east winds are a hazard to both forestry and agriculture.

(vii) Growing season. The growing season has been determined by the method described by Anderson and Fairbairn (1955), and it is found to be 192 days for tree growth and 221 days for grass growth. The rainfall is well distributed over the growing season.

7. <u>Exposure</u>. The hills to the north-west, north and north-east and those to the south-east and south, all in the

region of 2000 feet, provide good geomorphic shelter for the site. In the immediate vicinity of the oakwood there is potential shelter from the mixed coniferous plantation to the south and west.

The greatest exposure is experienced in an east-west direction. In early spring dry east winds can cause much damage to grazings by "scorching" the herbage, while the prevailing south-west wind has an unhindered passage up Loch Linnhe, is then funnelled into Glen Spean as a west-south-west wind, and can cause damage in the form of windblow.

8. Geology. (i) Solid. The general geological formation on which this site lies is known as the Central Highland Granulites. This is a collective term and includes all the various types of granulites that constitute the Central Highland land mass. Constituents are chiefly quartz, muscovite, biotite and feldspars, the latter being present in large amount.

The specific rock type underlying this site is that of the Eilde Flags; quartzose felspathic schistose flags. In the oakwood the rock is not near the surface but it outcrops in, and forms the bed of, the River Spean.

The other formations in this area, which are also included under the general name "Central Highland Granulites" are: Granite, Ballachulish slate, Ballachulish limestone, Leven schists and Eilde quartzite.

(ii) Drift. Probably two great ice centres contributed to the drift geology of this area. Certainly that of Rannoch Moor played a great part, its glaciers, according to Charlesworth (1957), radiating out to Loch Leven and Glen Nevis. Probably some glaciers swept both across and round the south-east corner of the Ben Nevis range and into Glen Spean, and were then deflected in a westerly and finally south-westerly direction. In addition, there were probably smaller glaciers moving down the northern slopes of the Ben Nevis range into Glen Spean to join the main westerly ice movement. Perhaps the Monar ice from the north also made its contribution, sending some of its radiating glaciers in a south-westerly direction.

Immediately to the north of the Ben Nevis range, on the lower slopes of the mountains, there is abundant morainic material. This has been substantially modified by later glacial phenomena.

There are parallel roads on the hills surrounding this area. According to Charlesworth (1957) there was a great ice-dammed lake in this region. "Glaciers from Glen Arkaig and Glen Eil converged upon Glen Spean (as the content of the Lochaber moraines proves), and aided by ice from Ben Nevis, ponded the drainage in lakes." The average level of the parallel road in Glen Spean is 855 feet and it can be seen on Meall nan Luath, just opposite and to the north of the oakwood, and also to the south-east on the lower slopes of Beinn Bhan. Thus the site of this wood was at one time under water, and the initial morainic material would have been overlain by lacustrine sediments and fluvioglacial material that was washed into the lake from the surrounding area. Charlesworth again mentions that another lake, at 420 feet, was formed, held by ice spanning the Spean at Tirandrish. The point immediately opposite, and to the south of, Tirandrish, as mentioned in section 5, is where the topography of the oakwood changes, and it seems likely that to the west of this point is morainic debris released by the ice-dam as it melted, while to the east the drift material is lacustrine and fluvioglacial.

The drift material probably contains fragments of all the neighbouring rock formations, though only the following were identified: granite, slates, mica schists, quartzite and the quartzose felspathic schistose flags (Eilde flags).

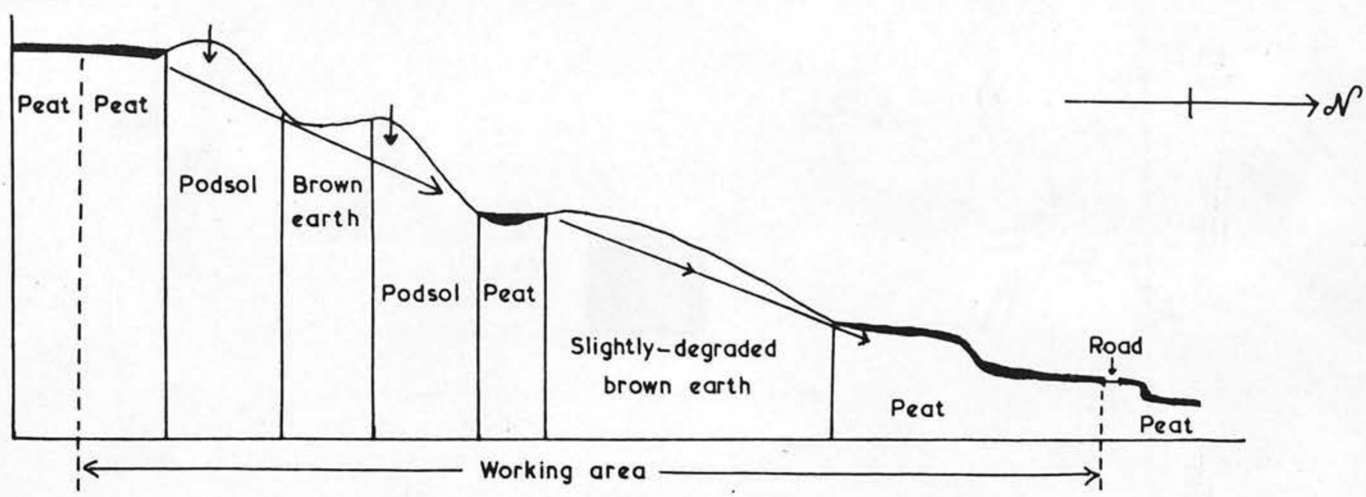
9. Soils. (i) General. The parent material of the soils in this area can be regarded as boulder till. Fertility varies from moderate to low. Weathering of the granulites releases acid feldspars, the quartz fraction breaking down to give a sandy, gravelly soil. The schists contribute the clay fraction, from the weathering of the mica, together with their main constituent elements of iron, magnesium and potassium. The weathering of the quartzite and granite elements in the boulder till will increase the mineral constituents mentioned above, though granite will also contribute alkali feldspars. In addition, there is probably limestone in the drift material, from the Ballachulish limestone formation which is to the east and south of this site.

The soil of the eastern third of the area is on lacustrine and fluvioglacial material, while the rest of the oakwood lies on boulder till that has been modified in places by fluvial action (Plate 66).

As rainfall is high in this region and the surface soil free-draining, it is the degree of slope which ultimately determines the character of the soil profile.

(ii) Soil types. Four soil types have been recognised: podsol, slightly-degraded brown earth, brown earth and peat. The following composite cross-section indicates where each of these types occur.

Composite profile, Killiechonate oakwood.



Arrows indicate leaching.

Distances not to scale.

(a) Podsol. This soil type is found on the high ground on the south side of the site and on the top of the knolls, where drainage is good and a mor humus is present. Leaching occurs in both vertical and lateral directions, as shown

Plate 66. A quarry on the edge of the oakwood shows the typical texture of the soils in this site.

in the diagram. Lateral leaching is indicated by the presence of a thick leached layer under the B horizons.

The podsols to the east are on material of lacustrine and fluvioglacial origin and therefore on the surface are predominantly sandy, gravelly or clayey, with few stones. To the west of the site the podsols are on material of essentially morainic origin and as a result contain a high proportion of sub-angular stones and rocks.

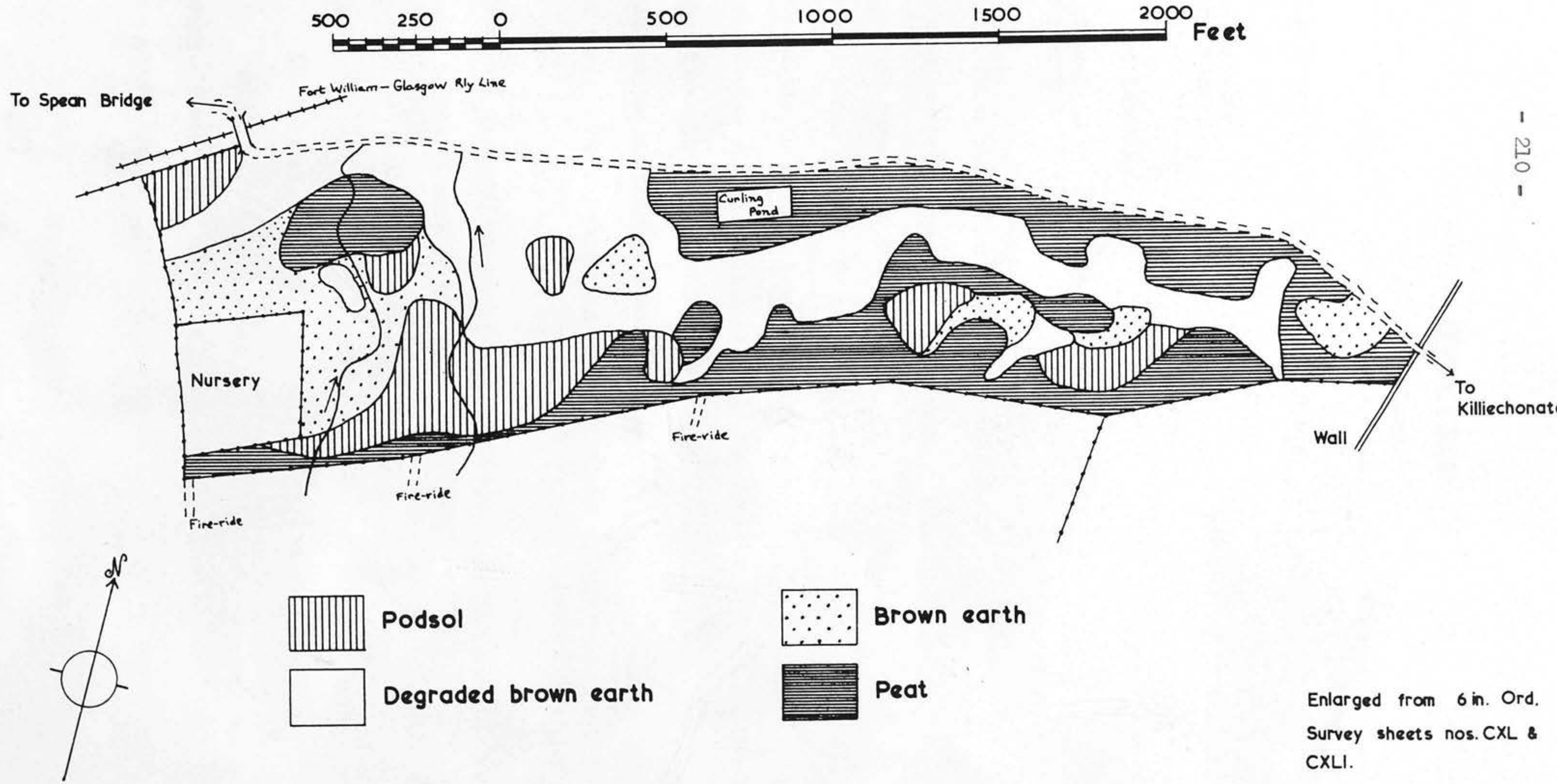
Description of soil profiles

	TOP SLOPES	MIDDLE SLOPES
Aspect:	NNE	NNE
Slope:	Moderate	Less than moderate
Stand:	Sessile oakwood	Sessile oakwood
Vegetation:	(i) Light bracken abundant. (ii) Mosses abundant and co-dominant under bracken. (iii) *Agrostis/Festuca* grasses less than abundant but co-dominant with mosses.	Same
A_{oo}	Slight accumulation of oak leaf litter, twigs and undecayed bracken fronds. Also remains of grasses and mosses.	Same
A_oF	1 in., slightly matted; fibrous; very dark brown.	Same
A_oH	4 ins. Black, compact, greasy mor.	$\frac{1}{2}$ in. Black, granular structure.
A_1	Nil	Very thin. Dark grey in colour.
A_2	3 ins. Strongly leached layer, white in colour.	$1\frac{1}{2}$ ins. Strongly leached layer, white in colour.

Killiechonate Oakwood

Soil Map

Scale 12 ins = 1 Mile



Enlarged from 6 in. Ord. Survey sheets nos. CXL & CXLI.

	TOP SLOPES	MIDDLE SLOPES
B_1	1 in. Fairly hard, dark brown pan. Penetrable by roots.	2 ins. Pale ochre.
B_2	2 ft. Dark ochre; no induration.	$>$ 3 ft. Dark ochre.
A?	Sandy, gravelly horizon. Mostly white in colour, but yellowish in places. Depth unknown; $>$ 1 ft. Horizon of lateral leaching.	
Rooting depth	Throughout profile to the bottom of B_2 horizon.	About 3 feet.

Fauna   Visible soil fauna was absent from both profiles.

Texture   Both profiles are predominantly a sandy clay. Gravel, small sub-angular stones, pebbles and rocks are all present throughout the profiles.

(b) Slightly-degraded brown earth. On the middle and lower slopes, which are moderate to gentle, leaching is not so intense and as a result the soil type is a slightly degraded brown earth. A mor humus is present which has a granular structure. Throughout the dark brown A horizon there are bleached grains of sand. The B horizon is a lighter brown and rooting takes place into this horizon and stops at three feet. No soil fauna was observed but worms must have been present as moles were active in much of the area having this soil type. Texture of the soil is a sandy clay, with a large crumb structure.

(c) Brown earth. Any moderately drained depression between the hillocks and ridges, where leaching is likely to be very low, contains a brown earth soil. Mineral-rich water from the high ground brings nutrients into these depressions and provided there is some drainage peat does not form. The vegetation changes on these sites, with Holcus species usually being dominant.

Description of soil profile

Aspect: NNE

Slope: Nil

Stand: Degrading sessile oakwood

Vegetation: Bracken light and abundant, Holcus species abundant and co-dominant with Agrostis species, mosses abundant, wood sorrel and hard fern frequent.

A_{oo} 1". This year's litter, decaying well.

A_oF Thin to nil.

A_oH 2". Granular mull, merging gradually into mineral soil.

A 12" av. Pale brown colour, fine crumb structure. Texture - sandy-clay.

B 15". Greyish-ochre colour. Very large crumb structure though there is a higher proportion of sand in this horizon than in the A. Also abundant sub-angular stones of many sizes.

Water table at $2\frac{1}{2}$ feet. There was probably a gley profile below this level and at this time the profile was undergoing reduction, due to an extended period of heavy rainfall before the soil pit was opened up.

There was no sign of any soil fauna in this profile but mole hills were abundant in this soil type.

(d) Peat. This varies in depth over the area from 6 inches to 18 inches and occurs where slopes are gentle to nil and the drainage correspondingly bad. It is also present in depressions were drainage is impeded. The peat is black in colour and greasy to the touch. The boulder till underneath is practically unweathered.

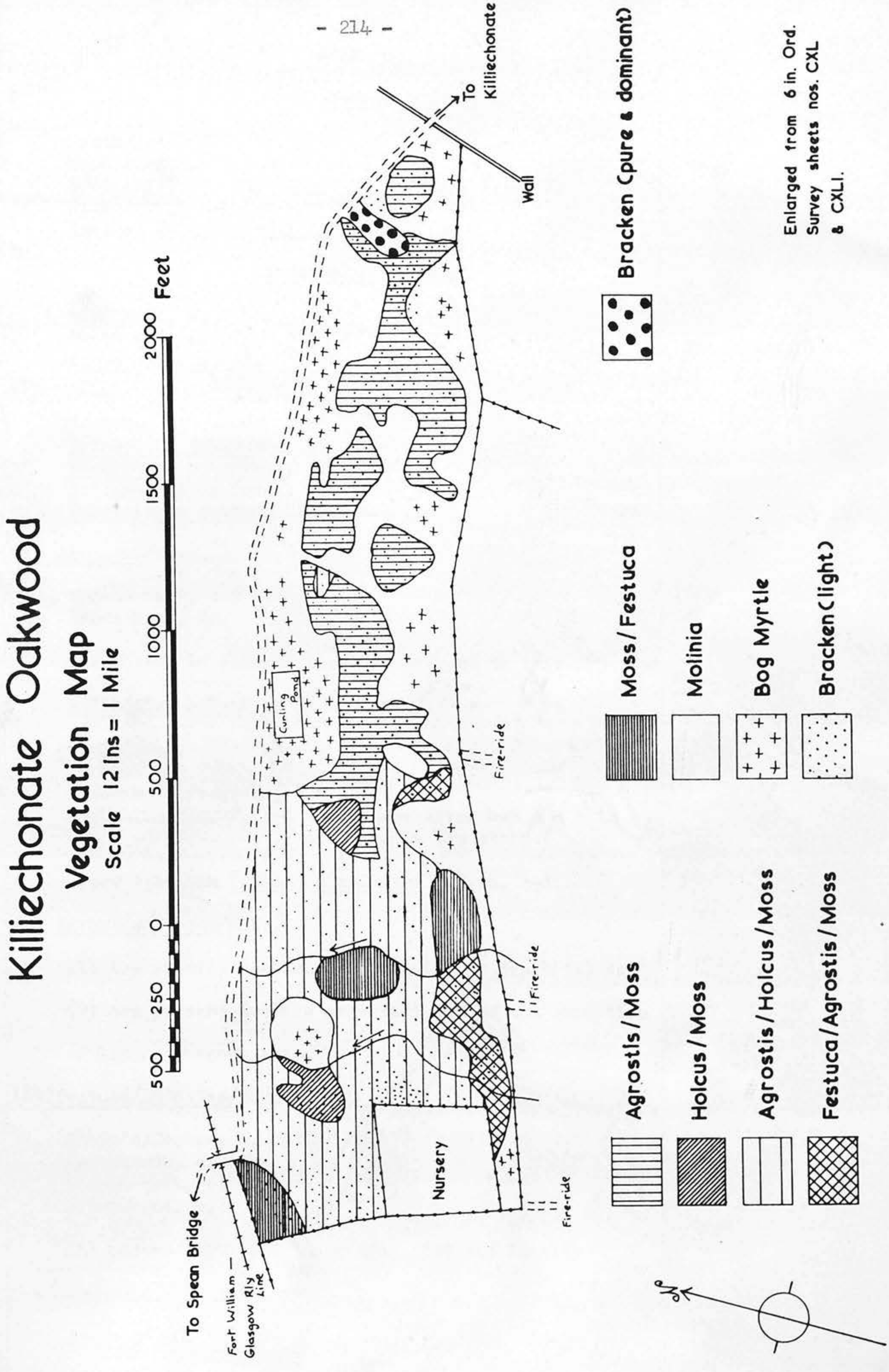
10. Drainage. This is dependent on the degree of slope, being good on all but the gentle slopes, where it is sluggish but not stagnant. Drainage is from south to north and there are several burns which carry the water away from the site. These, however, are in need of artificial improvement as they are often choked with branches, large stones, leaves, peat and silt. Some drains have been opened up but these, too, are in need of attention.

It is difficult to keep the drains in good repair in this area for water and frost erode the clay fraction of the boulder till very easily, whereupon large rocks, stones and clay slump into the drainage channel to block it.

11. Vegetation. This site was inspected and the vegetation described during November, 1961, which probably accounts for the paucity of herbs in the following descriptions.

In general, a grass/moss vegetation covers the area. The sward lacks density and mosses cover the soil wherever the grasses do not.

The following species occur throughout the oakwood and are not confined to any particular association:


Killiechonate Oakwood
Vegetation Map
Scale 12 Ins = 1 Mile
500
250
0
500
1000
1500
2000
Feet
To Killiechonate
Wall
Curling Pond
Fire-ride
Fire-ride
Fire-ride
Nursery
To Spean Bridge
Fort William — Glasgow Rly Line
Agrostis/Moss
Holcus/Moss
Agrostis/Holcus/Moss
Festuca/Agrostis/Moss
Moss/Festuca
Molinia
Bog Myrtle
Bracken (light)
Bracken (pure & dominant)
Enlarged from 6 in. Ord. Survey sheets nos. CXL & CXLI.

Herbs

Heath bedstraw, la.
Wood sorrel, la.
Creeping buttercup (Ranunculus repens L.), lf.
Bilberry (Vaccinium myrtillus L.), lf.
Heather (Calluna vulgaris L.), lf.

Grasses and rushes

Soft rush, a.
Sweet vernal, lf.
D. caespitosa, lf.

Mosses

Hylocomium splendens, a.
Pleurozium schreberi, a.
Dicranum majus Turn., a.
Polytrichum commune Hedw., a.

(1) Agrostis/Moss.

Common bent, d & a.
Brown bent, lf.

All mosses in general list are present in this type but Hylocomium splendens is dominant.

(2) Holcus/Moss.

Creeping Soft-grass, d & a.
Yorkshire fog, f, s-d under tree cover but d & a in openings in the stand.

Green sphagnum (Sphagnum palustre L.), a, s-d.

(3) Agrostis/Holcus/Moss.

All the species mentioned in vegetation types (1) and (2) are present in this association with the exception of Green sphagnum moss.

(4) Festuca/Agrostis/Moss.

Sheep's fescue, a, c-d.
Red fescue, a, c-d.
Common bent, a, c-d.
Brown bent, o.

All mosses mentioned in general list are locally abundant.

(5) Moss/Festuca

Mosses mentioned in general list are locally dominant and abundant.

Leucobryum glaucum (Hedw.) Schp., lf.

Sheep's fescue, f.

(6) Molinia

Purple Moor-grass (Molinia caerulea (L.) Moench), d & a.
Deer grass (Trichophorum caespitosum (L.) Hartman), lf.

Erica species, o.
Carex species, lf.

Red sphagnum (Sphagnum plumulosum Roll.), lf.

Bog myrtle (Myrica gale L.), la - o.

(7) Bracken (pure and dominant).

Bracken, d & a.

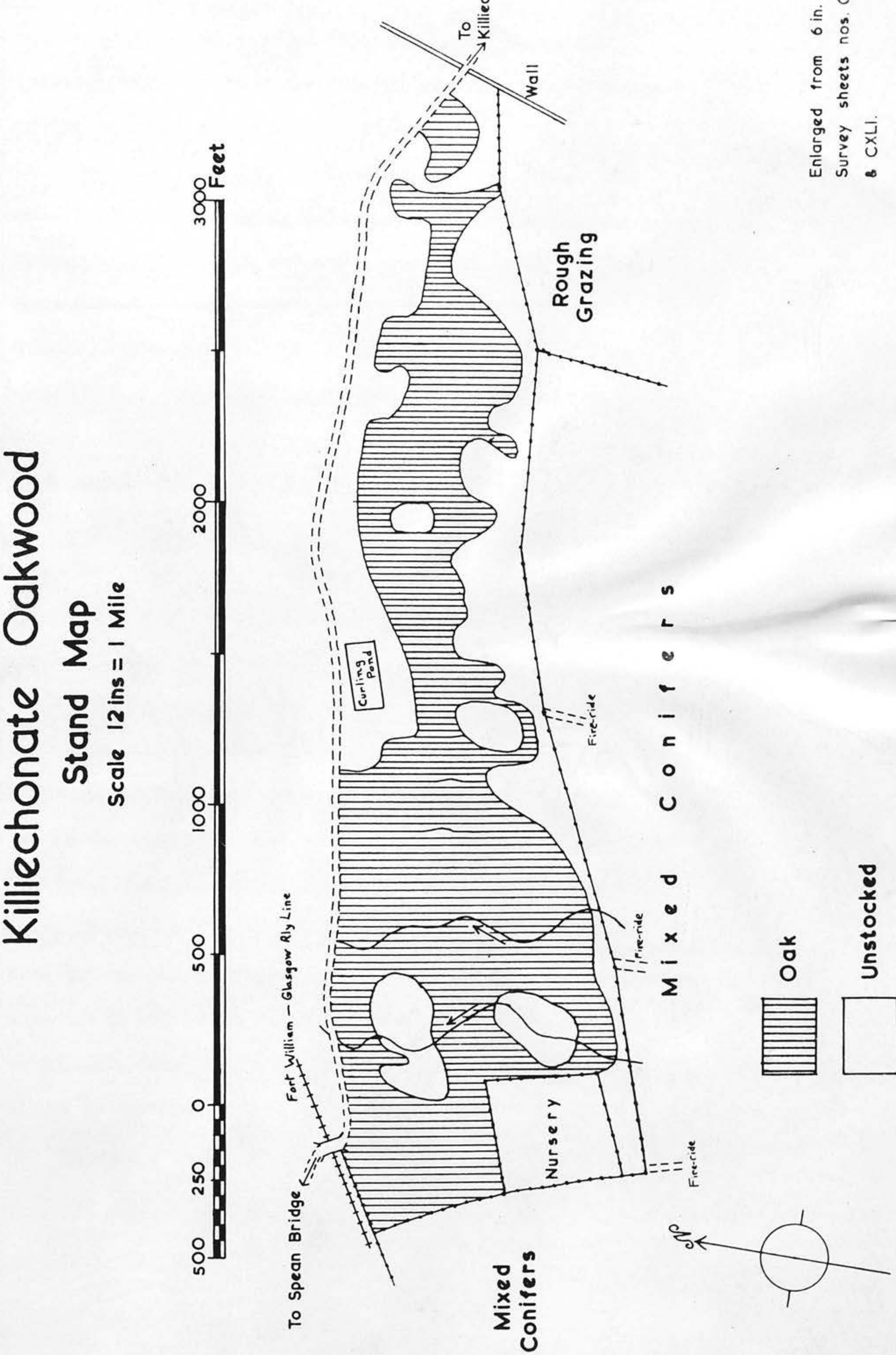
Vegetation type	Acreage	Acreage as % of total area
1. Agrostis/Moss	10.5	$19\frac{1}{2}$
2. Holcus/Moss	1.1	2
3. Agrostis/Holcus/Moss	15.8	$29\frac{1}{2}$
4. Festuca/Agrostis/Moss	2.2	4
5. Moss/Festuca	2.9	$5\frac{1}{2}$
6. Molinia	20.3	$37\frac{1}{2}$
7. Bracken (pure and dominant)	0.6	1
8. Curling pond	0.5	1

12. Harmful influences. The main potential destructive agency is fire. The Fort William-Glasgow railway line is near the northern boundary of the oakwood and with the adjacent vegetation being Molinia the fire hazard is high.

Dry east winds in spring can be serious as they scorch and kill the new growth of grass.

Grazing has resulted in a complete lack of natural regeneration.

Plate 67. Oak in well-defined lines suggests that the wood has been planted.


Killiechonate Oakwood
Stand Map
Scale 12 ins = 1 Mile
500 250 0 500 1000 2000 3000 Feet
To Spean Bridge
Fort William – Glasgow Rly Line
Curling Pond
To Killiechonate
Wall
Rough Grazing
Fire-ride
Nursery
Mixed Conifers
Mixed Conifers
Oak
Unstocked
Enlarged from 6 in. Ord. Survey sheets nos. CXL & CXLI.

that they have been planted (Plate 67). Ring counts indicate that the trees are 100-105 years old and they are in the medium to large timber stage.

6. Form and condition. On the whole the form of the oak is good, branching is not too heavy considering the openness of the stand, and there are many straight stems. However, the condition of the stand is on the decline. Stag-headedness is present in some trees while in others many of the large, lower branches are starting to decay. Frost crack is not uncommon and the timber is shaken and of poor quality.

7. Natural regeneration. After good mast years regeneration of oak is abundant, but few seedlings survive beyond the second year due to grazing. Birch and rowan regeneration is also present but it is heavily browsed.

8. Stocking and volume. The stocking of the wood increases slightly from east to west so three temporary sample plots were laid out, one in the eastern third and two in the remaining part of the wood. It was found that the total stocking in the east is 50 trees per acre (of oak only, 47 per acre) while in the west it is 66 trees per acre (of oak only, 61 per acre). So few birch and rowan occurred in the stand that for the purpose of stand volume calculation they have been ignored. The resulting volume of oak is approximately 1,380 H.ft per acre.

9. Acreage

(i)	Total acreage:	53.9 acres
(ii)	Present productive:	34.8 acres
(iii)	Present unproductive:	18.6 acres
(iv)	Potentially productive:	53.4 acres

Plate 68. Predominantly Molinia vegetation along the southern boundary of the site.

Plate 69. Molinia vegetation along the southern boundary, separating the mixed coniferous plantation (left) from the oakwood (right).

C. PAST AND PRESENT TREATMENT

1. Forestry. The oakwood has never received any planned or regular treatment. Birch has been cut out over the years for charcoal and firewood and hence it has practically disappeared from the stand. Very little oak has been removed but it has been exploited whenever required for a special purpose.

As far as present treatment is concerned the stand will not receive any attention, except for the maintenance of a bulldozed fire-ride which runs through the northern part.

2. Grazing. (i) Season of use. No planned grazing takes place now in this wood because there is no way of preventing stock from straying on to the main road. This happened in the past, especially with cattle, and it was considered unsafe to use the wood.

(ii) Type of stock. At present only stray sheep and roe deer frequent the wood, the latter increasing in number.

(iii) Stocking. Of sheep, virtually nil, and roe deer unknown.

(iv) Condition of vegetation. The condition of the grazing is poor. Bracken is present over a large area of the wood and is probably a factor contributing to the lack of density of the grasses. Mosses also occupy a great deal of the useful soil space while Molinia accounts for $37\frac{1}{2}\%$ of the vegetative cover. The shepherd estimates that 70 ewes could be wintered in the wood at present without resorting to hand feeding.

Plate 70. Molinia and bog myrtle vegetation along the northern boundary (looking west).

Plate 71. Firebreak ploughed in Molinia/Trichophorum vegetation with a prairie buster. The thin layer of peat is being colonised by Festuca and Agrostis species.

(v) Water. Water can be obtained from the burns which run through the site.

(vi) Damage to the stand. The trees are beyond the stage when they can be easily damaged by stock. However, casual grazing prevents regeneration from becoming established.

D. POSSIBLE FUTURE TREATMENT

1. Controlling factors.

(i) Objects of management. The general objects of management are:

(1) the maximum commercial production of timber consistent with good silvicultural practice, with the locality factors, especially soil and elevation, dictating the choice of species, and

(2) the integration of forestry and agriculture where possible.

Special objects of management for the site are:

(1) to provide an efficient firebreak to protect the coniferous plantations to the south of the area;

(2) to act as shelter for vegetation and livestock, and

(3) to maintain the amenity of the area.

The first special object of management is particularly important. The main Glasgow-Fort William railway line is close to the northern boundary and the adjacent vegetation, as well as that bordering the mixed coniferous plantation, is pure Molinia. Consequently there is a high fire hazard for most of the year.

(ii) Requirements for out-wintering. Dry east winds

Plate 72. A 1-acre clearing in the oakwood, accessible to machinery, and suitable for improvement of vegetation. (On Stand Map, the clearing immediately to the east of and adjacent to the nursery: looking north.)

in spring can scorch the tender, young grass growth and it is therefore desirable to provide shelter for the herbage. Shelter for livestock is of secondary importance but also desirable.

(iii) Site. The site is near the home farm and would provide valuable shelter and grazing during winter. At present, however, the flock of 600 blackface ewes and gimmers cannot come below 700 feet on Beinn Bhan as there is no downfall through the Forestry Commission's plantations, though there is a narrow passage way to lower ground but the sheep do not use it of their own accord. Furthermore, before the oakwood can be safely used for out-wintering livestock, a cattle grid will have to be installed at some point on the road to Spean Bridge west of the bridge over the railway line to prevent livestock from straying on to the main A86 road.

2. Sylvo-pastoral objective.

Both the general and special objects of management, together with the requirements for out-wintering, indicate that attention should be concentrated on the vegetation of this site. The provision of grazing sheltered from damaging winds and a reduction in fire hazard (i.e. integration of forestry and agricultural interests) could both be achieved by improving the *Molinia* vegetation, which covers more than a third of the area (Plates 68 to 70), to more valuable herbage which would remain green and relatively uninflammable.

Plate 73. An area suitable for improvement within the stand.

Plate 74. A small opening in the stand which could be enlarged and after improvement of the vegetation would provide an area of sheltered grazing.

Therefore it is suggested that the sylvo-pastoral objective should be the creation of sheltered areas of improved grazing in openings in the stand and under selected heavily-thinned areas, with groups of regeneration scattered throughout an irregular high forest of mixed hardwoods and conifers, the whole being used only during the winter months.

An irregular high forest of mixed hardwoods and conifers seems desirable in order to combine amenity, production, shelter and a reduced fire hazard. A group method of regeneration could be used to maintain irregularity of the stand for continuous shelter. The groups would need protection from browsing and this could be provided by polythene or nylon netting tied to the large trees surrounding the groups. Alternatively, the method suggested in Chapter 10, section 4, using tensioned galvanised wire with the large peripheral trees acting as stobs, could be tried. It is suggested that not more than 10 acres should be enclosed for regeneration at one time. This would reduce the grazing area from 53.4 to 43.4 acres.

The improvement of vegetation could be achieved by ploughing or some other method of cultivation. This is demonstrated by a firebreak adjacent to the site (Plate 71) which was ploughed with a prairie buster several years ago, converting a Molinia/Trichophorum vegetation type into a Festuca/Agrostis type. Cattle have congregated on this strip, dunging it heavily, which has further improved the

Plate 75. A knoll unsuitable for improvement of vegetation as it would be difficult for machinery to cultivate the moderately steep slopes.

Plate 76. Uneven ground, more suitable for regeneration than improvement of vegetation.

vegetation. All the Molinia could probably be improved in this way, and it is recommended that fertilisers be applied after cultivation. If adequate funds are available, reseeding would speed up the process of improvement and ensure that desirable forage species colonised the bare ground, rather than the natural grasses.

Areas for improvement should include those openings in the stand which are accessible to machinery (Plate 72) and also areas within the stand which are flat enough to allow cultivation (Plates 73 & 74). The latter areas would need thinning to allow sufficient light to reach the forest floor for satisfactory growth of future herbage. Wherever possible these areas should be at least one acre if the improvement operations are to be economic.

It is envisaged that the clearings containing improved vegetation should be devoted indefinitely to grazing, while those areas of improved vegetation within the stand will eventually be planted up again.

The silvicultural choice of species for this site are: sycamore, oak, ash, beech, Japanese larch and Noble fir (*Abies procera* Rehd.). The trees with dense canopies - sycamore, oak, beech and silver fir - should preferably be restricted to those sites which are likely to remain continually under trees, though this may not be possible in every case. The light-canopied trees, ash and Japanese larch, should be planted on the areas within the stand where the vegetation has been improved so that herbage is affected as little as possible. Natural regeneration of oak, birch and rowan occur occasionally in the wood and should be accepted, the oak preferably with the dense-canopied and the birch and rowan with the light-canopied trees.

3. Short term treatment (Next 5 years).

Drainage will be required before cultivation takes place. Generally only surface drains are necessary to cut off the continual seepage of moisture from higher ground. The two burns in the west of the wood could act as main drainage channels but at least one main channel will be needed in the east of the wood.

After drainage the *Molinia* areas should be ploughed and fertilisers applied, followed if possible by reseeding. The areas within the stand could probably be dealt with satisfactorily by a heavy harrow or disc cultivator. Only light grazing should be permitted on the improved areas for several years so that vegetation has a chance to become well established.

Regeneration should begin in any openings in the stand which are not suitable for improvement as described above, for example in the clearing shown in Plate 65. It should then proceed to the knolls and slopes of knolls (Plates 75 & 76) and finally on to the areas within the stand where the vegetation has been improved. Regeneration will need protection from livestock for a period of 10 to 20 years, depending on the species. Thereafter the groups could be re-opened to grazing and further areas enclosed.

4. Long term treatment.

Thinning operations in areas where the vegetation has been improved within the stand should aim at maintaining sufficient shelter against harmful winds yet allow enough light into the wood for herbage growth. A canopy of 60% is suggested as a guide but the actual density must be dictated by the condition of the ground vegetation.

It may be found that the area of improved vegetation bordering the north-east of the wood is not sufficiently sheltered from harmful winds in which case the margin should be planted up.

If grazing only during the winter allows the vegetation to become rank, it is suggested that cattle should be depastured in the wood for a few months during the summer to keep the vegetation in good condition for winter use.

As the soil contains a high proportion of clay it seems likely that it may suffer from compaction due to grazing. A careful watch should be kept for any signs of detrimental changes to the stand.

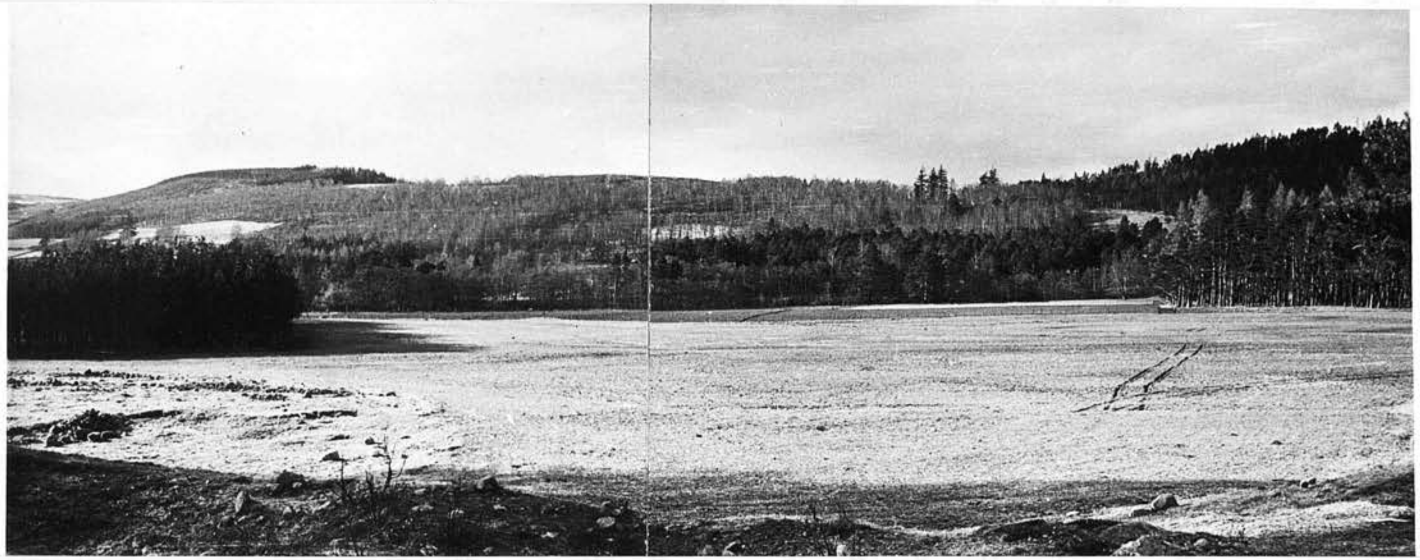


Plate 77. General view of the birchwoods, Glen Tanar (middle- and background).

SITE 3

BIRCHWOODS, GLEN TANAR

A. SITE

1. Location. The 1" Ordnance Survey map reference is 475965. The site is in the parish of Aboyne and Glen Tanar, in the county of Aberdeen, and is situated 5 miles south-west of Aboyne, between the Rivers Tanar and Dee.

2. Estate, farm and owner. The site is part of the Home Farm on the Glentanar Estate, owned by The Right Honourable Lord Glentanar, K.B.E.

3. Boundaries. The southern boundary is a post-and-wire fence for almost its entire length, with a small portion in the west being a stone wall. Post-and-wire fences also delimit the area to the west and north. In the east a stone wall, skirting in-bye land, is initially the boundary, giving way to a post-and-wire fence bordering a metalled road.

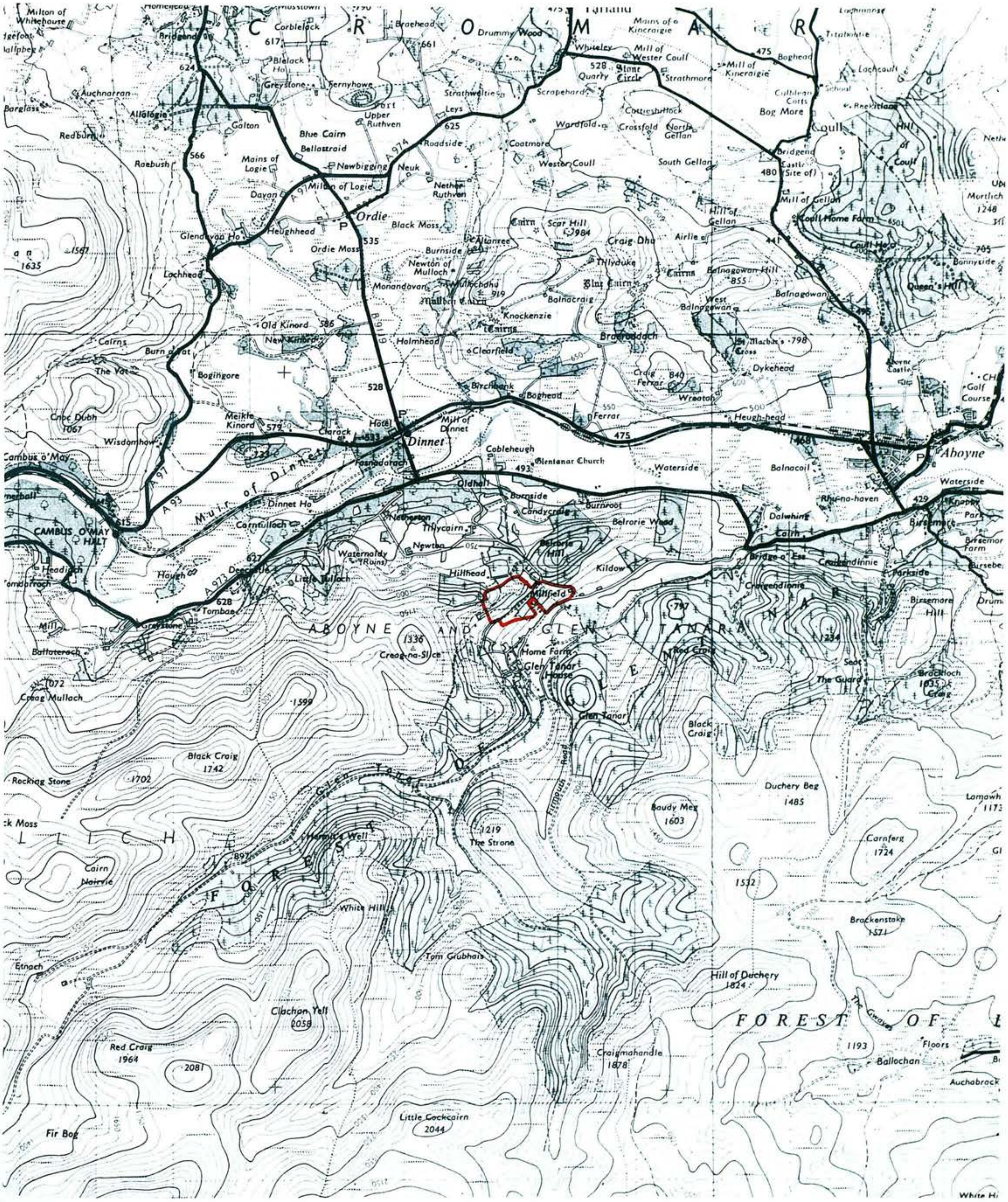
The site is divided into three sections by post-and-wire fences and the woodland runs across it as a strip, being narrow at the south-west and widening out as it runs north-eastwards.

There are two areas of reclaimed arable land in the western section, separated by unfenced woodland, and an area of improved pasture in the central section. Coniferous woodland adjacent to much of the working area provides considerable shelter.

4. Altitude. The range of altitude is from 550 feet in

Locality Map for the birchwoods, Glen Tanar

Scale 1" = 1 Mile (Extract from Ord. Survey Sheet 42)



the south-east to 950 feet in the west. The high ground in the north-west is in the form of a ridge.

In the immediate vicinity of the site the hills rise to 1,000 feet. Belrorie Hill to the north-east is just over 900 feet, Creag-na-Slice in the south-west 1,136 feet.

5. <u>Topography</u>. The site is on the southern side of a spur between the Dee and Tanar valleys, overlooking the River Tanar, and the land slopes in a north-west - south-east direction. The lower ground of the working area has gentle slopes of 8^{o} (14%), becoming moderately steep in the middle slopes, 15^{o} or 26%, and steep in the upper slopes, 16^{o} or 29%, thereafter levelling out on top of the ridge with gentle slopes.

Aspect in the east is south-east, becoming south-south-east in the west.

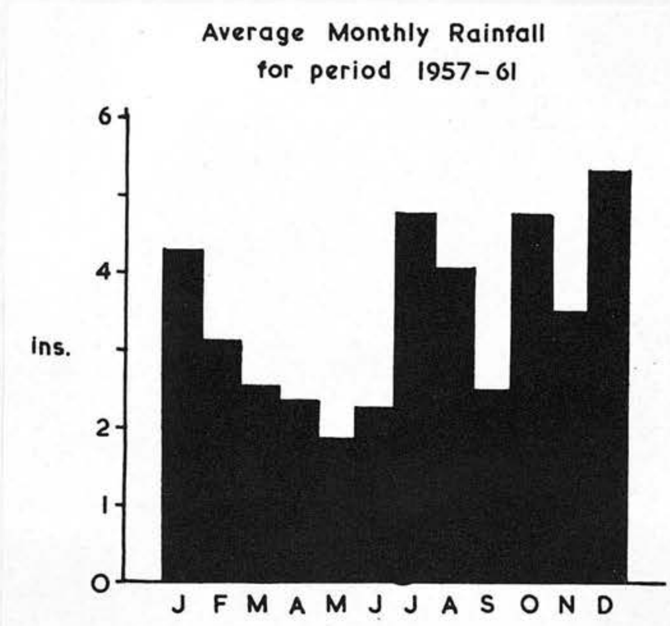
6. <u>Climate</u>. (i) Climatic zone. This area lies in the Alb climatic sub-region for which the meteorological data is as follows:

Mean range of temp. °F.	Mean min. temp. °F.	Days of frost	SUNSHINE June. Mean hrs/day.	SUNSHINE Year %	Growing season rainfall. ins.
26	34	100+	5.5 - 6.5	27	under 15

(ii) Rainfall. Records of rainfall have been kept since 1939 and the average for the period 1939-61 is 38.5 inches per year, while for the five-year period 1957-61, shown below, it is 41.4 inches, 7% higher than the 23-year average.

Mean monthly rainfall (Glentanar House) for period 1957-61; ins.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
4.3	3.1	2.5	2.4	1.9	2.3	4.8	4.1	2.5	4.8	3.5	5.3	41.4



The wettest month is December and the driest is May.

(iii) Snowfall. There is no data for the number of days of snow lying at 0900 hours but the following table shows the average number of days on which precipitation fell as snow.

Av. no. of days on which snow fell. 1957-61.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
6	5	4	2	0	0	0	0	0	0	0	3	20

Snowfall is often heavy and can be expected from December to April, with occasional falls in May and November.

(iv) **Temperature.**

Av. temps. for 5-year period 1957-61. ^{o}F.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly	29.6	31.6	36.2	39.9	44.8	50.3	51.8	51.2	47.9	43.2	35.6	29.7
Mean monthly minima	23.2	23.5	28.8	30.6	33.9	39.6	41.4	41.4	37.4	35.0	28.5	23.7

The coldest month is January and the warmest July.

(v) Frost. No accurate data is available but an estimate can be made from the mean monthly minimum temperatures given above, and it seems likely that ground frost will occur on at least 120 days per year. Late spring frosts are prevalent.

(vi) Wind. The prevailing wind is westerly.

(vii) Growing season: for trees - 142 days
for grass - 179 days.

The growing season for trees commences in the first week of May and ceases about the first week in October, and the rainfall during this period is approximately 15 inches.

7. Exposure. On the low ground there is good geomorphic shelter from all points of the compass. The higher part is exposed to the north-west, north and north-east though the blocks of coniferous woodland adjacent to the site provide local shelter.

8. Geology. (i) Solid. The area is mainly on a bed-rock of quartzose-mica-schist, with impure limestone to the west, quartzite to the north and granite to the south-east.

(ii) Drift. Ice movement in this region was in an easterly direction down the valley of the Dee, and glacial material of the above rock types are distributed haphazardly over the area.

9. Soils. The soil parent material over the whole site is a deep boulder till of moderately low fertility. Large angular blocks of rock are distributed liberally over the surface and throughout the soil, making the use of machinery on this land very difficult.

A soil map has not been included in this study as the soils are homogeneous, a brown earth type covering the whole site. Gleying occurs occasionally and very locally on the lower ground where drainage is poor.

Two soil pits were opened, one in the birch stand and the other in the open, and are described below.

Soil pit 1. In birch stand.

Aspect:	SE
Slope:	Gentle to moderate
Stand:	Pure birch
Vegetation:	*Agrostis/Festuca* (d & a), *Ranunculus* species and *Plantago* species (f), *Rhytidiadelphus squarrosus* (a).
A_{oo}	Thin. Birch leaves and twigs and dead grass stalks and leaves.
A_o	Indistinguishable.
A	4". Dark chocolate brown colour in which humus is mixed with the mineral matter. Loamy texture with fine crumb structure. Angular rocks and stones of all sizes very abundant. Tree and grass roots throughout horizon. Moles present but no worms observed.

B $>32"$. Yellowish-brown in colour. Signs of gleying at a depth of 8" (i.e. 1 foot from the surface). Sandy-gravelly texture with a high clay content; angular stones and rocks abundant. Very large blocky structure. Rooting depth of trees to $2\frac{1}{2}$ feet. Worms absent.

Soil pit 2. Open ground.

Aspect: SE

Slope: Gentle

Vegetation: Agrostis/Festuca (d & a), bracken (f) and Rhytidiadelphus squarrosus (a).

A_{oo} Thin layer of remains of last year's bracken fronds and grass stalks and leaves.

$A_{o}F$ Indistinguishable.

$A_{o}H$ $\frac{3}{4}"$. Dark brown crumbly mull.

A 12". Dark brown colour; humus mixed with mineral matter. Well-drained loam with fine crumb structure. Angular stones of all sizes plentiful. Worms abundant and rooting throughout horizon.

B $>20"$. (Soil pit only dug to 20" due to abundance of rocks). Yellow ochre colour. Stony-clay-loam texture. Large crumb structure apparent in pockets of clay-loam. Rooting depth to 6" in this horizon. Drainage good.

10. Drainage. In general the area is well drained except for a few depressions. These could be improved by opening the choked ditches.

11. <u>Vegetation</u>. An <u>Agrostis/Festuca</u> association is dominant throughout the area, with other species becoming co-dominant as the environmental conditions vary.

(1) <u>Agrostis/Festuca</u>

Common bent, a, c-d.
Sheep's fescue, a, c-d.
Yorkshire fog, la.
Sweet vernal, locally very frequent (lvf)
<u>Agrostis canina</u>, lf.
Crested Dog's-tail, lf.
Rough-stalked Meadow-grass, lf.
Creeping bent (<u>Agrostis stolonifera</u> L.), lf.
Cocksfoot (<u>Dactylis glomerata</u> L.), o.
Common Quaking grass (<u>Briza media</u> L.), f.

Sheepsbit (<u>Jasione montana</u> L.), f.
Violet species, f.
Plantain species, f.
Yarrow (<u>Achillea millefolium</u> L.), f.
Bell heather (<u>Erica cinerea</u> L.), f.
Thistle species, lf.
Buttercup species, lf.
Sedges (<u>Carex</u> species), lf.
Ragwort species (<u>Senecio</u> species), lf.
Heath bedstraw, lf.
Cowberry, lf.
Heather, o.
Vetch species (<u>Vicia</u> species), r.
Wild white clover, r.

Compact rush, lf.
Heath rush, lf.
Jointed rush, lf.

The following mosses are abundant to locally abundant over the whole area and will not be mentioned in the remaining plant lists:

<u>Rhytidiadelphus triquetrus</u> (Hedw.), Warnst.
<u>R. squarrosus</u>.
<u>Pleurozium schreberi</u>.
<u>Hylocomium splendens</u>.
<u>Thuidium tamariscinum</u> (Hedw.) B & S.
<u>Pseudoscleropodium purum</u> (Hedw.) Flersh.

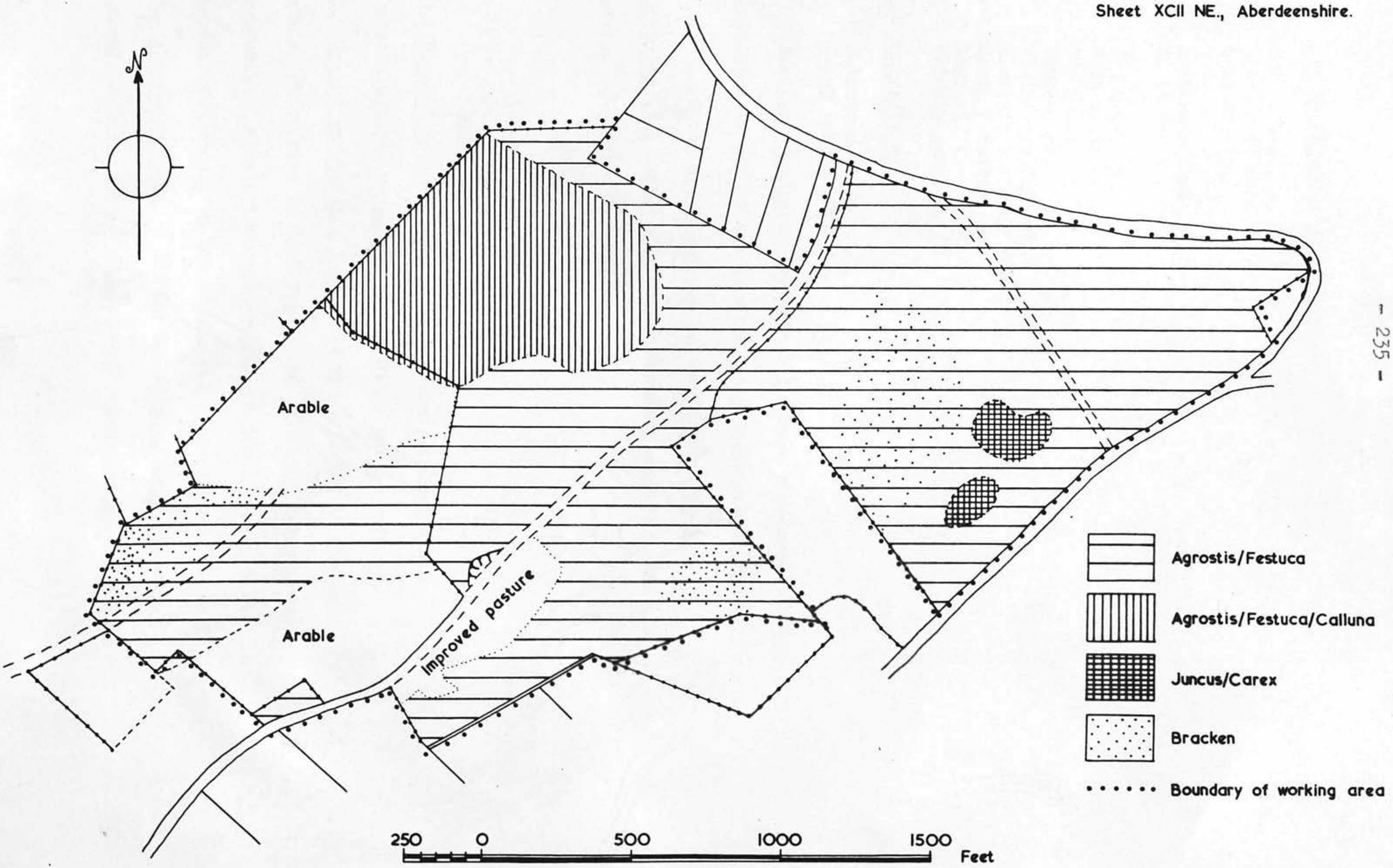
Plate 78. Looking south-west up Glen Tanar, which curves round to the left of the photograph.

Birchwoods, Glen Tanar

Vegetation Map

Scale 12 ins. = 1 Mile

Enlarged from 6" Ordnance Survey Sheet XCII NE., Aberdeenshire.



(2) Agrostis/Festuca/Calluna

Common bent, a, c-d.
Sheep's fescue, a, c-d.
Heather, la.

Yorkshire fog, f.
Sweet vernal, o.

Cowberry, vf.
Bell heather, vf.
Sheepsbit, vf.
Yarrow, vf.
Violet species, vf.
Plantain species, vf.
Heath bedstraw, vf.
Ragwort, f.
Thistle species, f.

(3) Juncus/Carex

Jointed rush, a, c-d.
Carex species, a, c-d.

Juniper (*Juniperus communis* L.) occurs abundantly in the south-east corner of the area but only occasionally elsewhere. Gorse (*Ulex europeus* L.) and Broom (*Sarothamnus scoparius* (L.) Koch) are locally abundant over the site and quickly colonise any disturbed land.

	Vegetation type	Acreage
1.	Agrostis/Festuca	69.7
2.	Agrostis/Festuca/Calluna	13.4
3.	Juncus/Carex	1.3

12. Harmful influences. Apart from grazing, which prevents natural regeneration, windblow can be serious.

13. Use of surrounding land. Stock-rearing is the main farming enterprise in Glen Tanar and most of the low ground is arable. Plantations occupy some of the low ground but are confined mainly to the middle and upper slopes (Plate 78).

14. Communications. Within the working area there are several tracks. The "Queen's Drive" runs through the middle

Plate 79. Dense broom forms the shrub layer under birch in some places.

of it and joins a metalled road at the northern end. This road borders the north-east boundary and connects with the main road out of Glen Tanar.

There is a regular rail service from Aboyne, 5 miles to the east, to Aberdeen.

B. STAND

1. Species. The main species is birch (*Betula verrucosa* Ehrh.) with a small area of Scots pine (*Pinus sylvestris* L.) in the north-east.

2. Structure. The Scots pine is single-storied high forest, while the birch is coppice with a shrub layer of broom in places (Plate 79).

3. Height. The timber height of the birch varies from 39 to 62 feet, the average being 49 feet. The Scots pine has an average timber height of 50 feet and an average top height of 76 feet.

4. Canopy. This varies very widely in the birch stand from nil in the gaps to about 60%. Probably an average canopy for the area would be 50%. For Scots pine the figure is 65%.

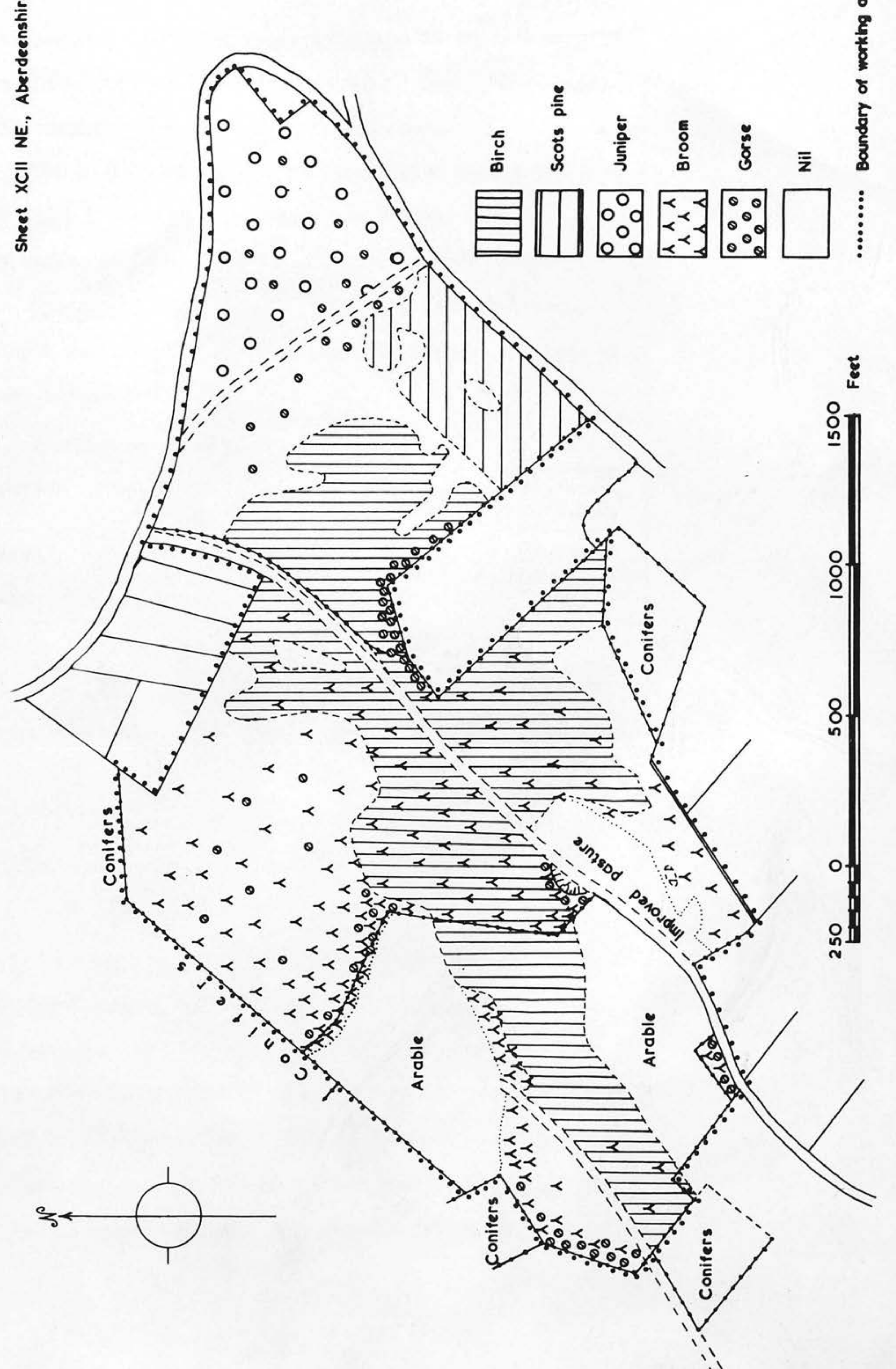
5. Origin, age and development stage. Both species have developed from natural regeneration. The birch has been coppiced and generally only one stem remains on each stool. Ring counts indicate that it is 88 to 90 years old, and it is in the small timber stage. The Scots pine is approximately 100 years old and in the large timber stage.

6. Form and condition. The birch is past maturity and

Birchwoods, Glen Tanar

Stand Map

Scale 12 ins. = 1 Mile



although the fungus Polyporus betulinus is present on some trees the majority are still healthy. The form is good, with compact crown and few heavy branches.

The Scots pine is of poor form, often having two stems and heavy branching for much of its height. Except on the dry knolls it is not healthy and windblow has occurred.

7. Natural regeneration. There has been occasional natural regeneration of birch but this is kept in check by heavy browsing.

8. Stocking and volume.

Species	Av. top ht. feet	No./acre	B.A./acre. H.ft.O.B.	Vol./acre. H.ft.O.B.
Birch	-	140	72.6	1,080
Scots pine	76	145	188	5,850

9. Acreage.

(i) Total	99.6	acres
(ii) Present productive	38.1	"
Birch	32.7	"
Scots pine	5.4	"
(iii) Present unproductive	61.5	acres
W. arable	7.3	"
S. arable	5.5	"
Improv. past.	2.3	"
Unstocked stand	46.0	"
Miscellaneous	0.4	"
(iv) Potentially productive	84.1	"

C. PAST AND PRESENT TREATMENT

1. Forestry. The woodlands have been used for grazing and out-wintering cattle and sheep for many years. The birch has had two thinnings since 1946 and in addition windblown material has recently been removed from the eastern section. One thinning has taken place in the Scots pine within the last few years plus the removal of windblown trees.

2. <u>Grazing</u>. (i) Season of use. The area is used for 8 months of the year, from October to May.

(ii) Type of stock. Highland and Cross Highland breeding cows and their calves use the area during the winter but blackface sheep also have access.

(iii) Stocking. Cattle; 130. Sheep; 430. During the winter the field gates are left open and the livestock can roam over the whole of the site except for the eastern section. However, as the cattle are hand fed they tend to congregate near the place of feeding, with the result that this area becomes over-used and badly poached while the remaining ground is little used.

(iv) Condition of vegetation. There are many indications that the area is over-grazed. Ground vegetation is very short and the arable land, which provides foggage during winter, is badly poached. In the *Agrostis/Festuca/Calluna* association heather is spreading at the expense of the grass species.

The shrub layer is also heavily browsed as can be seen by the Juniper in the eastern section, which now has a prostrate habit and rarely exceeds 18 inches in height (Plates 41 & 42). Gorse and broom are also eaten.

(v) Water. Water is obtainable from drinking troughs which are present in most fields.

(vi) Damage to the stand. There is no current natural regeneration. All trees and shrubs within reach of cattle are severely browsed, even birch branches up to $\frac{3}{4}$ in.

diameter being eaten. Occasionally large surface roots, particularly of Scots pine, have been damaged by animal hooves.

In the Scots pine stand ditches have been trodden in, leading to water-logging of the ground and windblow.

D. POSSIBLE FUTURE TREATMENT

1. Controlling factors.

(i) Object of management: "To bring the forest area to normality as soon as possible by planting of the bare areas, under-planting of scrub, natural regeneration and introduction of leaf trees and shade-bearing conifers for soil improvement where and when possible." Heavy volume producers are used and provision is made for experimental work in the field of silviculture.

Special objects of management for the site are:

(1) that the present area of woodland should remain approximately the same, and

(2) the land use should remain dominantly one of rough grazing.

(ii) Requirements for out-wintering. Snowfall is often heavy and winters are generally severe. As both cattle and sheep are hand fed during the winter the provision of natural grazing is less important than good shelter for successful out-wintering, and to achieve the latter conifers are preferred.

(iii) Site. All parts of the site are accessible and within easy reach of the Home Farm, which makes it particularly valuable for out-wintering as hand feeding can take place wherever desirable.

The Head Forester requires the retention of birch in future stands for the maintenance of soil fertility.

2. Sylvo-pastoral objective.

Bearing in mind that the area of tree cover should remain approximately the same and that birch is required in future stands, it is suggested that the sylvo-pastoral objective should be to establish, in a matrix of birch, 1-2 acre blocks of conifers primarily for providing overhead shelter for livestock, and sited so that livestock are encouraged to use the whole of the rough grazing area.

The stand map on page 243 shows possible locations and acreages of these blocks. Before they are finally felled further blocks should be planted in new positions and birch allowed to regenerate the clear-felled areas. In this way it should be possible to maintain a continuous tree cover and soil fertility over the area.

As the object of the coniferous blocks is to provide efficient overhead shelter they should be kept as dense as possible and it is suggested that the side facing the prevailing wind should have an impermeable stand margin, either by leaving the first two rows of trees unbrashed or by artificial means, such as wattle hurdles.

The silvicultural and agricultural choice of species do not conflict on this site. Forest management requires high volume producers and the argiculturist needs good shelter under conifers, both conditions being satisfied by Douglas

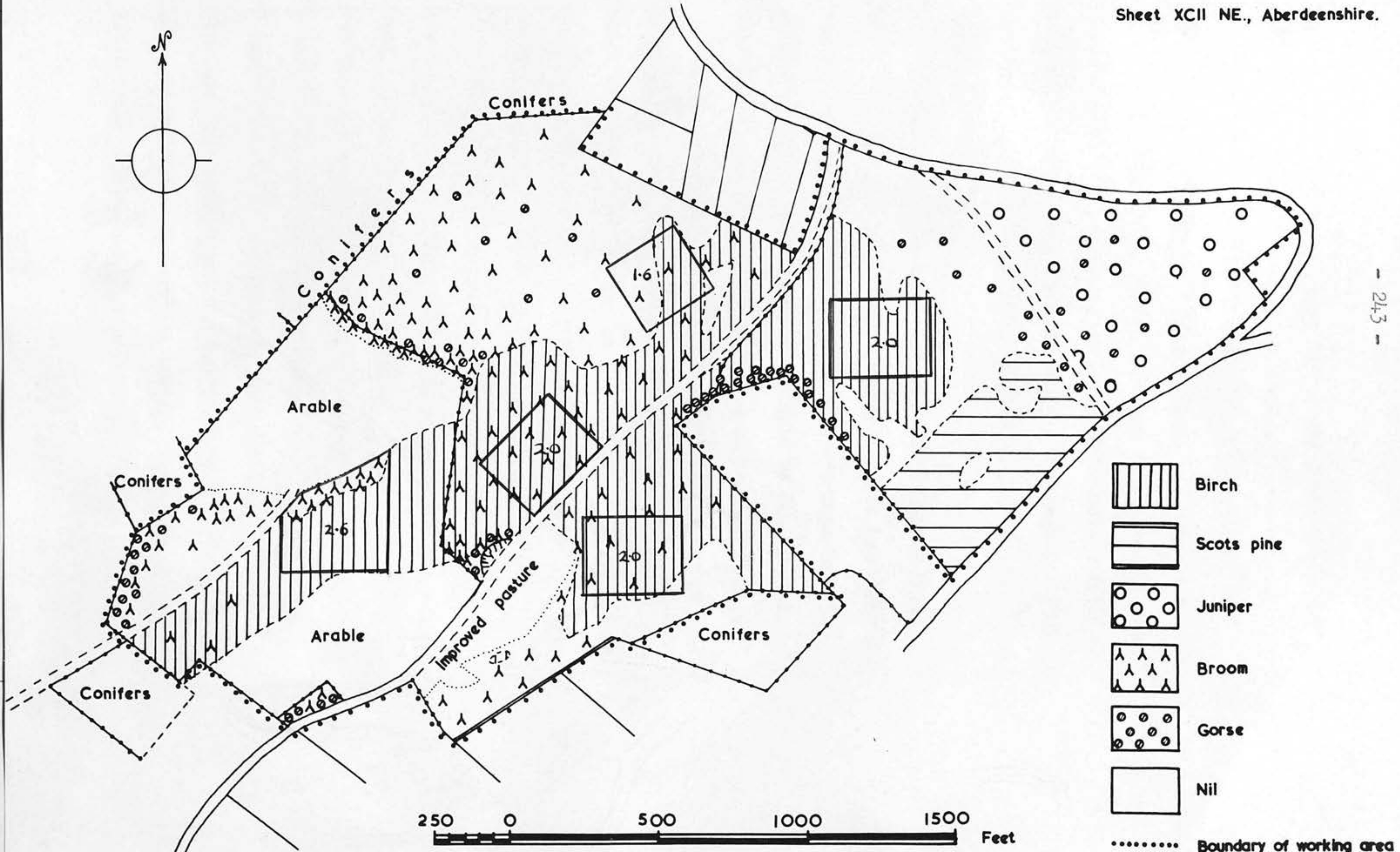
Birchwoods, Glen Tanar

Stand Map

Scale 12 ins. = 1 Mile

Enlarged from 6" Ordnance Surve

Sheet XCII NE., Aberdeenshire.



fir, Noble fir (Abies procera Rehd.) and Scots pine, the latter to be planted instead of Douglas fir in exposed situations.

3. Short term treatment (Next 5 years)

The birch is decadent and windblow occurs nearly every year, so that it is unlikely to survive for more than 15 to 20 years. It is essential, therefore, to regenerate this species as quickly as possible and before planting the coniferous blocks.

In order to leave a sufficient area of tree shelter accessible to livestock it is recommended that the birch be regenerated in two phases, dealing with approximately 16 acres in each. The regeneration should be distributed throughout the present area in groups of about 1-2 acres.

It is suggested that the sites for the coniferous blocks be selected immediately and pegged out on the ground. The birch area which they occupy at present (10.2 acres), plus another 6 acres, will provide the overhead shelter for livestock during the first phase of regeneration.

Natural regeneration could probably be obtained, providing the grass sward is broken up to expose the mineral soil. This could be done mechanically over most of the site but where this is not possible on account of steep or boulder-strewn ground, hand screefing in small patches (about 2 feet square at intervals of 1 yard) would suffice.

After ground preparation the areas would need fencing and polythene or nylon netting attached to peripheral trees of the regeneration area would seem the easiest material to use for these groups. The method of fencing described in Chapter 10, using tensioned galvanised wire with trees acting as stobs, could also be tried, omitting the protective hardwood blocks in this instance as the birch has little value other than firewood.

Before the birch catkins cast their seed, the tree cover on the regeneration areas should be heavily thinned to leave 60 to 80 mother trees per acre. If there are catkins on the felled trees the slash should be spread over the mineral soil so that the seeds can be cast on the most favourable seed bed. If sufficient natural regeneration is not obtained within $2\frac{1}{2}$ years after the seeding felling artificial regeneration must be used.

Protection should continue until the trees are considered to be out of danger from browsing, which will probably involve a period of from 8 to 10 years. As soon as this stage is reached the second phase of regeneration can be started.

Broom and gorse are likely to be troublesome weeds and will probably need constant cutting back to prevent the birch from being suppressed.

4. <u>Long term treatment</u>.

The second phase of regeneration involves the establishment of the 5 coniferous blocks and the regeneration of the remaining area of birch, the latter being treated in the same way as in Phase 1. During Phase 2 livestock will be able to use the recently regenerated birch areas as shelter.

Following ground preparation fencing must again precede natural regeneration and planting, for which it may be possible to salvage the materials used in Phase 1.

After the trees are out of danger from browsing the areas should be re-opened to livestock and the whole site will have been regenerated.

To maintain the tree cover on the site, group regeneration of birch can be obtained in future by coppicing. The coniferous blocks will be clear-felled eventually and before this takes place it is suggested that other blocks be planted in new positions, the planting again to be in two phases. In Phase 1 two blocks should be planted and after opening them to livestock two of the original blocks can be felled and the area regenerated with birch. The second phase would involve the establishment of 3 more blocks, followed by the clear-felling of the remaining 3 old coniferous blocks and the area regenerated with birch. This completes the cycle of regeneration for the whole area.

The Scots pine in the eastern section need not receive attention until the birch has been regenerated and the coniferous blocks established. Juniper should be encouraged and gorse and broom kept in reasonable amount, as all can be a useful source of food in times of snow.

It is recommended that the present uneven distribution of livestock over the area during the winter months should be rectified before the coniferous blocks become accessible, for they are unlikely to remain healthy under heavy and prolonged use.

SITE 4

PINEWOODS, GLEN SHIRRA

A. SITE

1. Location. The plantation is situated 15 miles south-west of Newtonmore and 3 miles north of the north-east tip of Loch Laggan and is in the parish of Laggan in the County of Inverness. On the 1" Ordnance Survey map it can be found between 540925 and 548935.

2. Estate and owner. The plantation and surrounding land is owned by the British Aluminium Company Limited.

3. Boundaries. The site is triangular in outline. Beginning at the north-east corner and moving southwards, the boundary is initially a post-and-wire fence, to the east of which is the estate sawmill. After reaching Loch Crunachdan, the western edge of the Loch forms the boundary which is not static since the water level of the Loch fluctuates considerably, being controlled by a tunnel at the south-western end connecting with Loch Laggan. A derelict post-and-wire fence delimits the site on the west while to the north the boundary is a metalled road.

4. Altitude. This ranges from 880 feet at the lochside to 975 feet at the north-west corner. The average altitude is approximately 900 feet.

Immediately to the south Meall an t-Sithein rises to just over 1,550 feet and to the east of this the hill is just over 2,000 feet. Across the River Spey to the north the ground rises to nearly 2,000 feet on Meall an Domhnaich

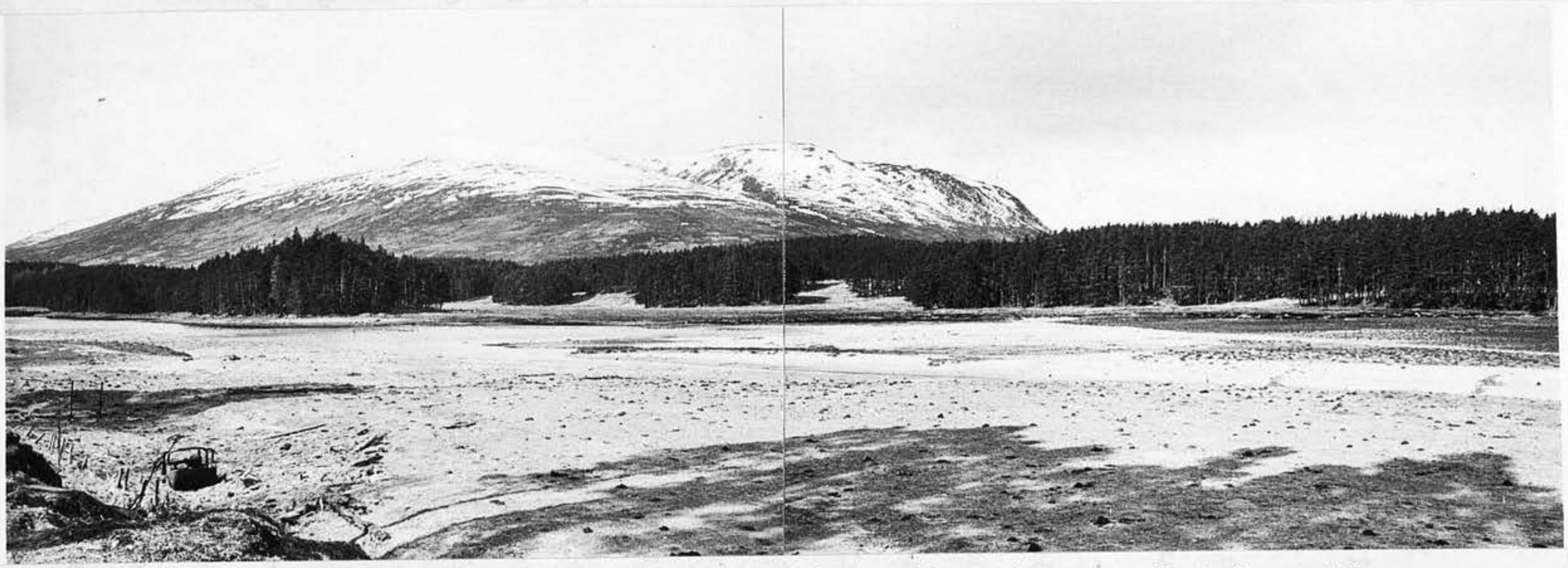
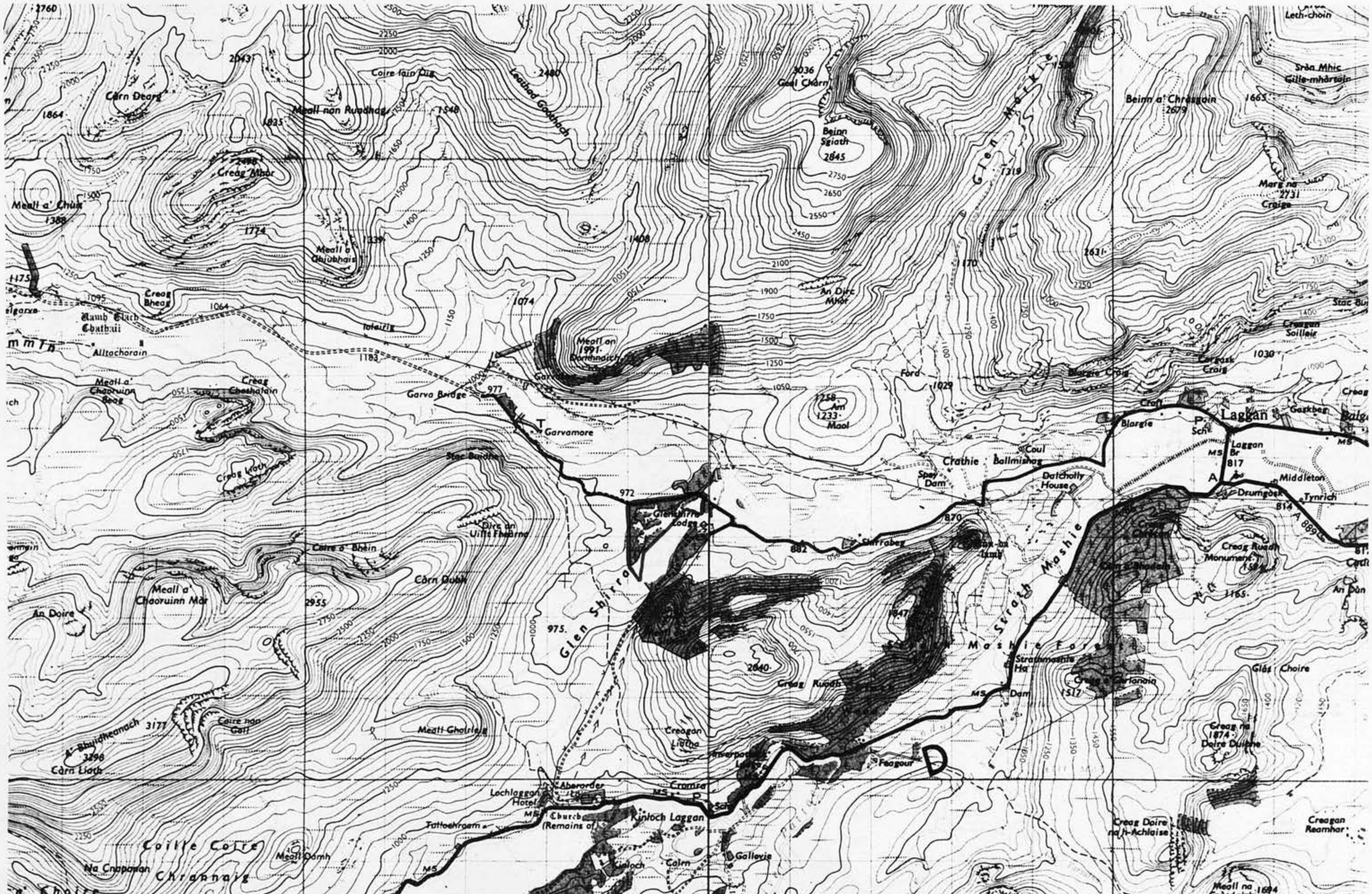


Plate 80. The Pinewoods, Glen Shirra, looking north-east across Loch Crunachdan. Glen Shirra recedes on the left and the Spey Valley on the right.

Locality Map for the pinewoods, Glen Shirra

Scale 1" = 1 Mile (Extracts from Ord. Survey Sheets 36 & 37)



while to the west it reaches over 3,000 feet.

5. Topography. This site is at the junction of two Glens; Glen Shirra, running in a south-west - north-east direction, and the valley of the Spey, running west - east (Plate 80). The latter is a U-shaped valley, characteristic of glacial action, while all around there are many lochans, corries and hanging valleys, indicative of heavy glaciation at one time.

The topography of the valley bottom is one of numerous moraines between which the ground is flat or gently sloping to one or other of the rivers.

The pinewood shows these topographical features. There are knolls of morainic material of varying height and degree of slope, and the ground between them is covered with a thick layer of peat. This mound-and-hollow formation gives way on the south-east of the site to Loch Crunachdan.

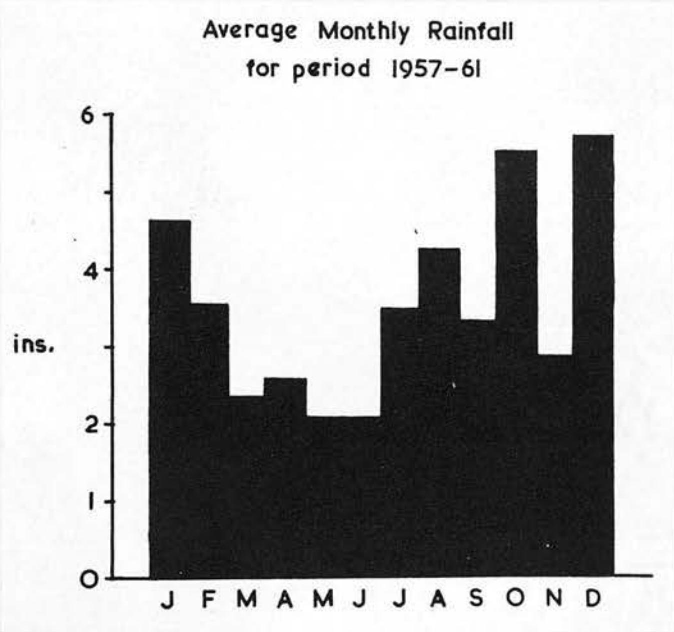
6. Climate. (i) Climatic zone. Although the site lies in the B3a sub-region the road forming the northern boundary, and the eastern edge of Loch Crunachdan, are common boundaries of the B2b and B3a sub-regions. It seems likely that conditions for the area will be intermediate between the two and accordingly information is recorded for both sub-regions.

Sub-region	Mean range of temp. °F	Mean min. temp. °F	Days of frost	SUNSHINE June. Mean hrs/day.	SUNSHINE Year %	Growing season rainfall. ins.
B2b	32	32	100	5.5 - 6.0	25	15 - 20
B3a	25	34.5	50-100	5.0 - 6.5	23	20 - 30

Plate 81. Looking southwards towards the site (middle-ground) from Meall an Domhnaich. Meall an t-Sithein in the background.

(ii) Rainfall. At the Spey Dam, $2\frac{1}{2}$ miles to the east, continuous readings of the rainfall have been kept since 1938. The following table is the average of the mean monthly rainfall for the period 1957-61.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
4.6	3.5	2.4	2.6	2.1	2.1	3.5	4.2	3.3	5.5	2.9	5.7	42.4



From March to June the mean monthly rainfall remains more or less constant, increasing to a maximum in December, with the exception of a sudden fall in November, and thereafter decreasing to a minimum in **May and June.**

(iii) Snowfall. No figures are available for this area but local inhabitants do not consider it to be one of heavy snowfalls.

The following data is a guide to the amount of snow that may fall in a year. It is for Dalwhinnie, 15 miles to the south-east at an elevation of 1,176 feet, 300 feet higher than the present site.

Av. no. of days of snow lying at 0900 hrs at Dalwhinnie. 1956-60.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
13	12	5	1	0	0	0	0	0	0	2*	4	37

* = 3-year average.

(iv) Temperature. In the absence of any recorded temperatures for this district the Dalwhinnie figures have been used, with a correction of +1°F for every 300 feet decrease in altitude, assuming the altitude of Dalwhinnie to be 1,200 feet and the working area 900 feet.

Mean monthly temp. in °F for 5-year period 1956-60.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
32.5	33.2	38.9	42.6	46.6 *	53.0	54.7	54.2	51.1 +	47.2 +	40.7 *	36.2

* = 3-year average
\+ = 4-year average

The mean monthly temperature rises from a minimum in January to a maximum in July, decreasing again to the minimum in January.

(v) Frost. From the data for this climatic sub-region 50-100 days of frost can be expected per year.

(vi) Wind. The prevailing wind is south-westerly. However, the local inhabitants believe that there has been an increase in the number of easterly winds in recent years.

(vii) Growing season. This was calculated according to the method described by Anderson and Fairbairn (1955) and was found to be 179 days for tree growth and 216 days for grass growth.

The growing season rainfall can be determined approximately from the rainfall figures together with the knowledge of the length of growing season for trees. The latter extends from May to October, all but a few days, and the rainfall for this period is approximately 21 inches.

7. Exposure. There is good geomorphic shelter from the hills to the south, west and north and moderate geomorphic shelter to the north-east and south-east. Exposure is high from the south-west, the prevailing wind having a clear passage down Glen Shirra, and to the north-west and east along the Spey valley.

8. Geology. (i) Solid. Undifferentiated metamorphic rocks underlie the area and do not outcrop in any place.

(ii) Drift. The knolls are boulder till and contain fragments of granite, mica schists, quartzite and quartzose-mica-schist. The depressions between the knolls are covered with a thick layer of peat.

9. Soils. On the morainic mounds the soil type is a well-defined podsol, with peat covering the remaining area.

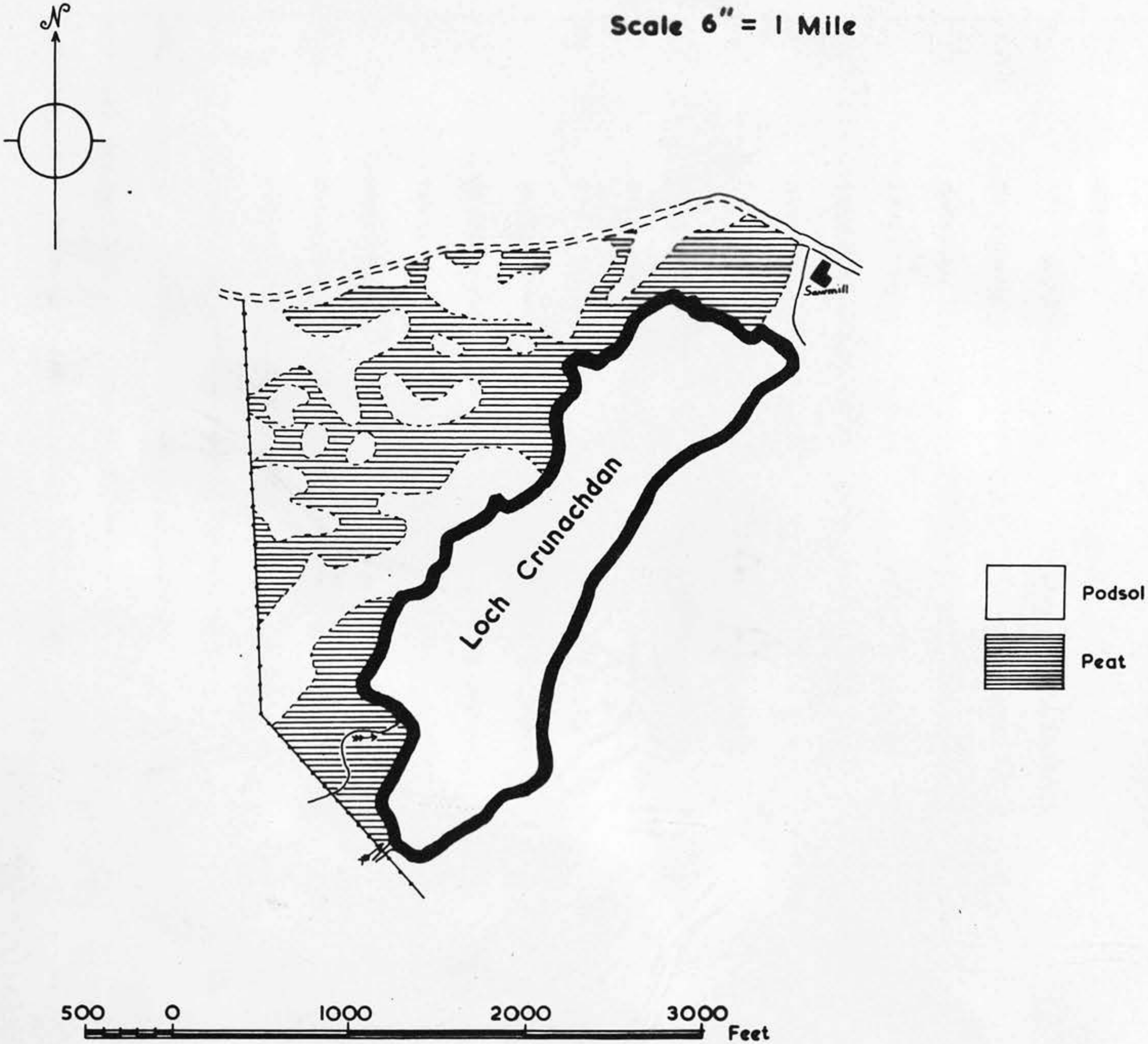
Description of podsol profile

Aspect:	S
Slope:	Gentle
Stand:	Pure Scots pine
Vegetation:	Mosses dominant, mainly *Hylocomium splendens* and *Rhytidiadelphus triquetrus*. Sheep's fescue frequent.
A_{oo}	Thin layer of branches, twigs, cones and remains of mosses and grasses.
A_oF	4". Brown, fibrous, with a platy structure.

Pinewoods, Glen Shirra

Soil Map

Scale 6" = 1 Mile



Extract from 6" Ordnance Survey Sheet CXV, Inverness-shire.

A_oH 1". Black, amorphous, greasy mor, merging into the next horizon.

A_1 $\frac{1}{4}$". Black; humus mixing with mineral matter. Sandy texture. Structureless. Roots throughout but visible soil fauna absent.

A_2 2". Grey-white, and sandy to gravelly texture. Structureless. Roots throughout and soil fauna absent.

B_1 3". Blackish-brown layer of humus accumulation. No induration present. Sandy texture with numerous small, sub-angular stones. Structureless. Soil fauna absent. Roots throughout this horizon which merges gradually into the next.

B_2 6". Dark brown colour. Sandy texture with numerous sub-angular stones. Structureless. Soil fauna absent and rooting throughout.

B_3 8". Browny-yellow layer of sandy-gravelly texture, with a large number of angular stones. Structureless. Soil fauna absent and rooting takes place to approximately the bottom of this horizon.

C Morainic debris. Angular stones of all sizes, gravel and greyish to yellowish sand. Very compacted with no rooting in this material.

10. Drainage. The morainic mounds supporting tree growth are well drained but the depressions are almost permanently waterlogged. There are several small streams running

through these hollows which drain into the Loch.

In the north of the area timber extraction has resulted in the choking of drains leading to accumulation of surface water and occasional windblow.

11. Vegetation. Under most of the tree cover on the mounds mosses are dominant while a flora characteristic of peat exists in the hollows.

(1) Festuca/Agrostis

Limited to a relatively small area in the northern part of the site. It occurs on the morainic mounds under pine and also as a fringe round the north-east side of the flat, peaty area near the sawmill.

Common bent, a, c-d.
Sheep's fescue, a, c-d.
Red fescue, lf.
Agrostis canina, lf.

Heather, lf.
Bilberry, lf.
Cowberry, o.

Hylocomium splendens, va.
Rhytidiadelphus triquetrus, la.
Pleurozium schreberi, la.
Thuidium tamariscinum, lf.

(2) Festuca/Moss

This type differs from (1) in that Festuca species (mainly Sheep's fescue) are co-dominant with mosses (same species and order of frequency as (1)), with Agrostis species occurring only occasionally.

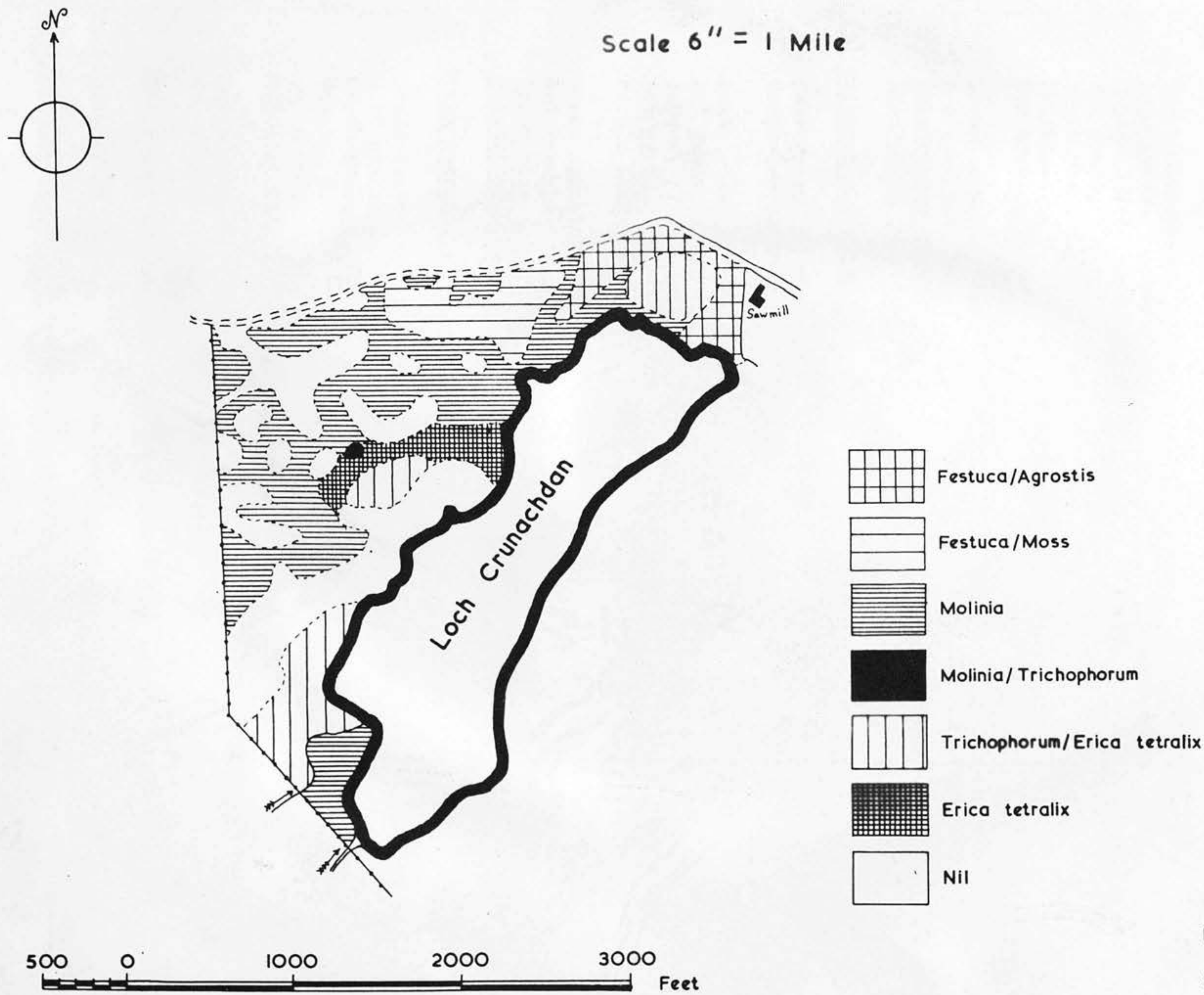
(3) Molinia

Purple Moor-grass, d & a.
Tufted Hair-grass, lf.
Agrostis species, lf.

Pinewoods, Glen Shirra

Vegetation Map

Scale 6" = 1 Mile



Extract from 6" Ordnance Surv[ey]

Sheet CXV, Inverness-shire.

Soft rush, la.
Jointed rush, locally occasional (lo).

Green sphagnum, la.
Polytrichum commune, o.
Red sphagnum (Sphagnum plumulosum Roll.), o.

(4) Molinia/Trichophorum

Purple Moorgrass, a, c-d.
Deer grass (Trichophorum caespitosum (L.) Hartman) a,c-d.
Cross-leaved heath (Erica tetralix L.), a, s-d.
Mat grass, f.
Heath rush, f.
Sedges, f.
Bog myrtle, f.

Green sphagnum, la.
Red sphagnum, la.
Polytrichum commune, f.
Hylocomium splendens, f.

(5) Trichophorum/Erica tetralix

Deer grass, a, c-d.
Cross-leaved heath, a, c-d.

Heath rush, a, s-d.
Mat grass, f.
Sedges, f.
Bog myrtle, f.
Purple Moor-grass, o.

Green sphagnum, la.
Red sphagnum, la.
Hylocomium splendens, f.
Polytrichum commune, lf.

(6) Erica tetralix

Cross-leaved heath, d & a.
Deer grass, f.
Heath rush, f.
Sedges, f.
Bog myrtle, f.
Bog asphodel (Narthecium ossifragum (L.) Huds.), lf.

Green sphagnum, la.
Red sphagnum, la.

Under most of the pine there is no vegetation apart from patches of mosses. Of these Hylocomium splendens is dominant and abundant, with the mosses mentioned in (1) of this series also occurring in the same frequency. In addition Leucobryum glaucum is found occasionally.

	Acreage	Acreage as % of total area
1. Festuca/Agrostis	7.0	7
2. Festuca/Moss	8.8	9
3. Molinia	35.1	35
4. Molinia/Trichophorum	0.2	-
5. Trichophorum/Erica tetralix	14.8	15
6. Erica tetralix	5.1	5
7. Nil	28.6	29

12. Harmful influences. Although windblow has not been serious it must nevertheless be considered as a potential source of danger. The area is exposed to the prevailing wind and to the north-east which, combined with the fact that the stands have not been thinned, makes the risk of windblow high.

Livestock have been partly responsible for damaging the drains, leading to waterlogging and windblow.

Many of the depressions between the knolls are frost hollows.

13. Use of surrounding land. Livestock rearing is the main farming enterprise in Glen Shirra. Arable land is confined to the better soils on the lower ground, with forestry on the poor soils and peat areas. The hill ground is mainly rough grazing at present but forestry will soon be equally important in the land use of this higher ground.

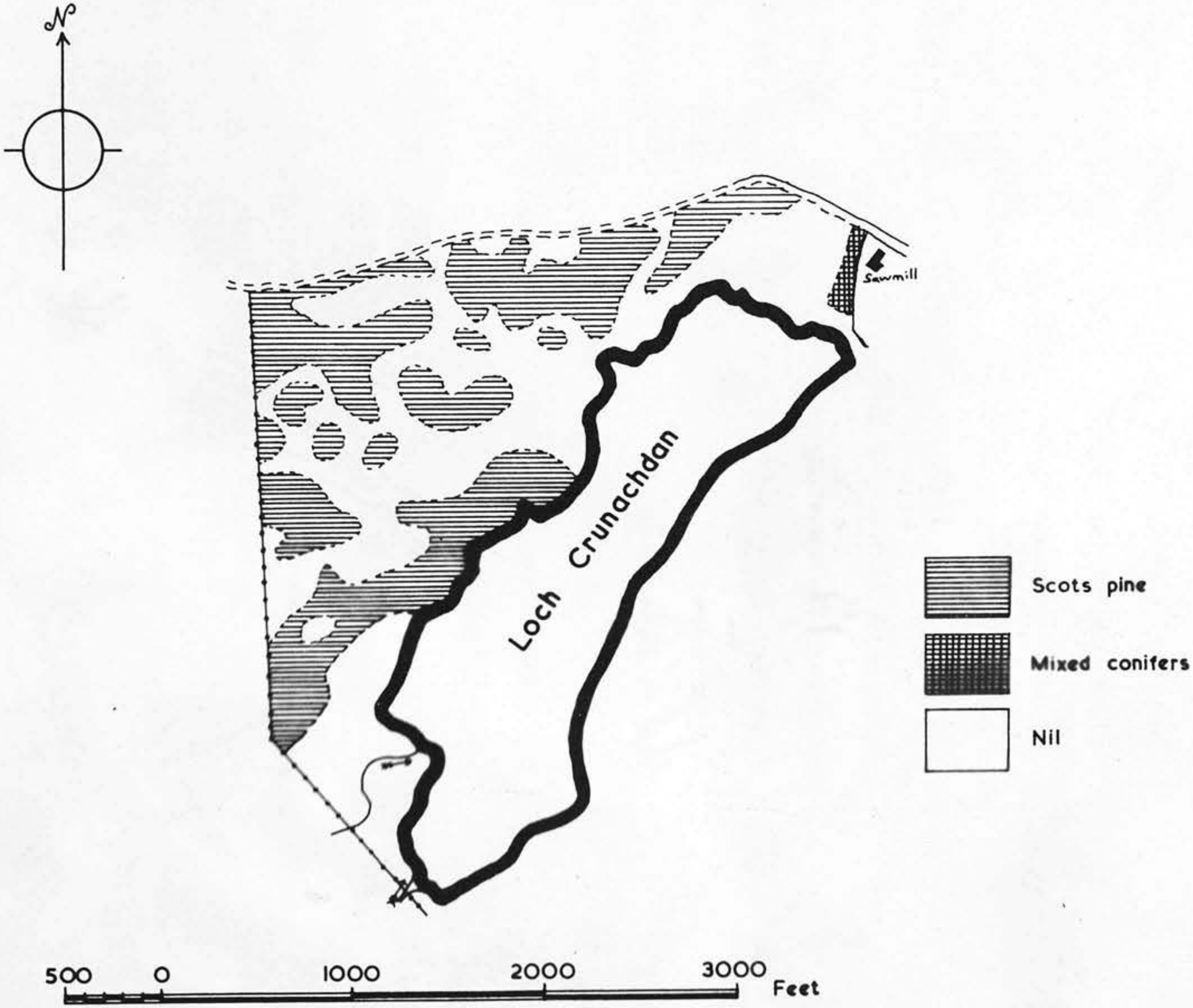
B. STAND

1. Species. Pure Scots pine dominates the area. At the north-east corner there is a small block of mixed conifers, mainly Scots pine with some Norway spruce.

Pinewoods, Glen Shirra

Stand Map

Scale 6" = 1 Mile



Extract from 6" Ordnance Survey

Sheet CXV, Inverness-shire.

2. Structure. Single-storied, even-aged high forest.

3. Height. Top height varies from 54 to 78 feet, the average being 66 feet.

4. Canopy. In the unthinned parts in the west and on the isolated mounds the canopy is 100%. After thinning it is on average about 75%.

5. Origin, age and development stage. The stand was planted probably between 1882 and 1887 as ring counts put the age of the stand between 75 and 80 years. It seems likely that the whole of the area was planted with Scots pine which failed on the peat areas.

6. Form and condition. Thinning has been neglected with the result that the crowns are deformed and too small for the age of the tree. It is doubtful whether crown development could be influenced at this stage even with heavy thinning, which would be unwise due to the risk of windblow. There are many sub-dominant, suppressed and dead trees but the dominant and co-dominants are healthy and much of the timber is of good quality.

7. Natural regeneration. This occurs occasionally and conditions on the mounds are good. Until recently, however, the dense canopy and constant use by livestock have prevented regeneration.

8. Stocking and volume.

Species	No./acre	Top ht. ft.	B.A./acre H.ft.O.B.	Vol./acre H.ft.O.B.
Scots pine	350	66	177	5,000

9. Acreage.	(i) Total	99.6	acres
	(ii) Present productive	42.8	"
	Scots pine	41.9	"
	Mixed conifers	0.9	"
	(iii) Present unproductive	56.8	"
	(iv) Potentially productive	99.6	"

C. PAST AND PRESENT TREATMENT

1. Forestry. Prior to current work the stands have received little treatment - one thinning at the most. The present thinning is a light one in order to avoid windblow.

2. Grazing. (i) Season of use. Sheep have access to the area from the beginning of December to the end of May. Cattle use the area from November/December to the middle of May, at which time they make their way to the hill pastures.

(ii) Type of stock. Blackface sheep, Highland and Cross Highland cattle, red and roe deer.

(iii) Stocking. 500 to 600 ewes and followers have access to the area plus a herd of 55 cattle and their followers. The number of deer using the site is unknown.

(iv) Condition of vegetation. The quality of the vegetation is poor, 35% being pure Molinia, which is of little value to livestock during the winter months, except as roughage. However, there are some evergreen species (Cowberry, rushes and sedges) and in spring the growth of several species starts early, for example deer grass and heath rush.

(v) Water. This can be obtained from the pools and streams in the area.

(vi) Damage to the stand. Physical damage to the trees is very slight and confined to the barking of surface roots along the more frequently used cattle and sheep tracks. However, as mentioned earlier, stock are responsible in part for damage to drains which has led to water accumulation and windblow in some cases.

D. POSSIBLE FUTURE TREATMENT

1. Controlling factors.

(i) Objects of management:

(1) the maximum commercial production of timber consistent with good silvicultural practice, with the locality factors, especially soil and elevation, dictating the choice of species, and

(2) the integration of forestry and agriculture where possible.

However, the special object of management for this site is to maintain or improve the amenity.

(ii) Requirements for out-wintering. The cattle are hand fed during the winter but the sheep are not. Thus, although shelter is more important than grazing for the cattle, the two are equally important for sheep.

(iii) Site. In the centre of the area the ground is very soft and there are many bogs. Access to the southern half is therefore difficult and of less importance for out-wintering cattle. Sheep, being lighter and more agile than cattle, can negotiate the soft ground and use the whole of the area during the winter.

2. Sylvo-pastoral objective.

To maintain the amenity of the area Scots pine should remain the dominant species, though Douglas fir is recommended as a subsidiary species, being an attractive tree, a high volume producer and providing good shelter. Both will be confined to the morainic knolls. It is considered that the Uniform silvicultural system would be appropriate as natural regeneration is a possibility, the regeneration period can be short and clear-felling is avoided, which is desirable in order to maintain amenity.

The centre of the site, which is boggy and dangerous for livestock, should be planted up with Sitka spruce (approximate area outlined in red on stand map, page 264). The necessary fencing would serve an additional purpose in keeping stock off the area.

As grazing is required for the sheep which use the site in winter it is suggested that the _Molinia_ and _Trichophorum/Erica tetralix_ vegetation types to the north of the blue line shown on the stand map on page 264 should be improved to _Agrostis/Festuca_ types if possible. _Molinia_ at present covers 35% of the site, and as it is of little grazing value during the winter, any reduction in area and improvement would be beneficial.

3. Short term treatment (next 5 years).

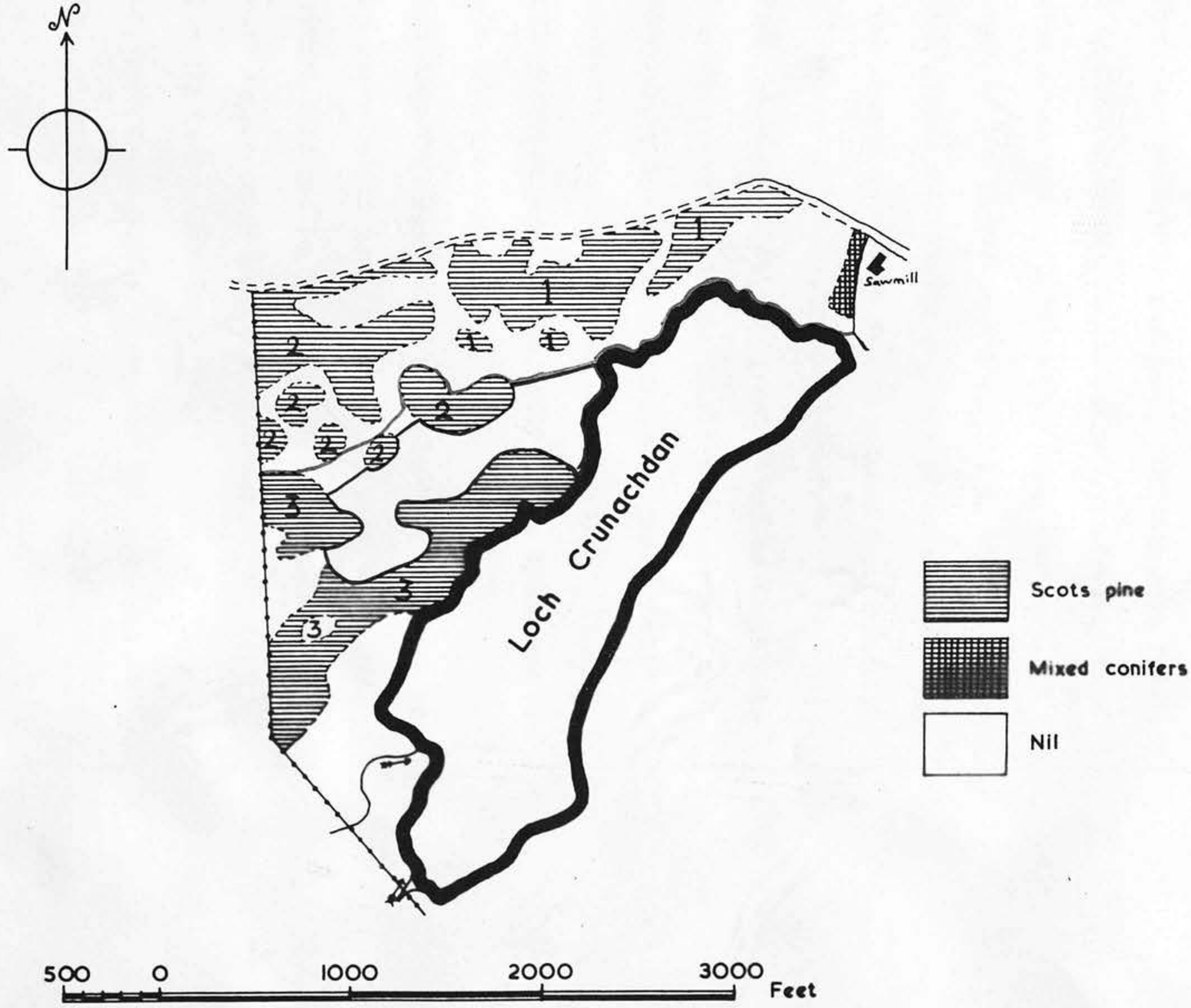
During this period the Sitka spruce area should be planted. A deer fence will be necessary for which nylon or polythene netting could be used.

The improvement of the vegetation should also be initiated and it is suggested that it should take the form of ploughing and fertilising wherever possible.

Pinewoods, Glen Shirra

Stand Map

Scale 6" = 1 Mile



Extract from 6" Ordnance Survey

Sheet CXV, Inverness-shire.

4. Long term treatment.

The regeneration of the pine areas should begin after the improvement of vegetation has been completed.

It is suggested that the Scots pine be divided into 3 sections, to which the numbers in red on the stand map in page 264 refer. The acreages of these sections are: 1 - 12.3 acres; 2 - 13.9 acres; 3 - 16 acres.

The blocks comprising Section 1 have been thinned and therefore regeneration is prescribed for this area first. A seeding felling should be carried out, preferably in a good seed year, leaving 60-80 mother trees per acre. Extraction of the timber should suffice to disturb the humus layer and expose the mineral soil but if this is not so, screefing should be carried out in patches approximately 2-3 feet square at intervals of 3-4 feet.

Deer fencing will then be required and as the blocks are irregular in outline it is likely that polythene or nylon netting, attached to the peripheral trees, would be less expensive than conventional deer fencing. It must remain in position until the majority of the trees are out of danger from browsing.

Secondary fellings should take place at intervals of from 3-5 years but if it is obvious that sufficient natural regeneration will not be obtained in a reasonable time, artificial regeneration should be employed.

When the tree growth in Section 1 is out of danger from browsing, the fences should be removed and regeneration operations started in Section 2. In this way there will always be two sections (approximately 27 acres) accessible to livestock. In time it may be possible to open the Sitka spruce block if the trees have lowered the water table sufficiently, but it would seem unwise unless the peat has dried out considerably as cattle may damage not only surface roots, but also those below the surface by sinking into the soft peat.

SITE 5

MEALL AN DOMHNAICH

A. SITE

1. Location. The site is approximately 6 miles west of the village of Laggan in the county of Inverness and the 1" Ordnance Survey map reference is 548953.

2. Estate and owner. The area is owned by the British Aluminium Company Limited.

3. Boundaries. The western, northern and eastern boundaries are clearly demarcated by a post-and-wire fence. Of the southern boundary, only the eastern quarter, formed by a post-and-wire fence, is distinct, the remainder being the edge of a felled stand.

4. Altitude. The average altitude is 1,500 feet. It ranges from 1,050 feet on the southern boundary to 1,991 feet at the top of Meall and Domhnaich.

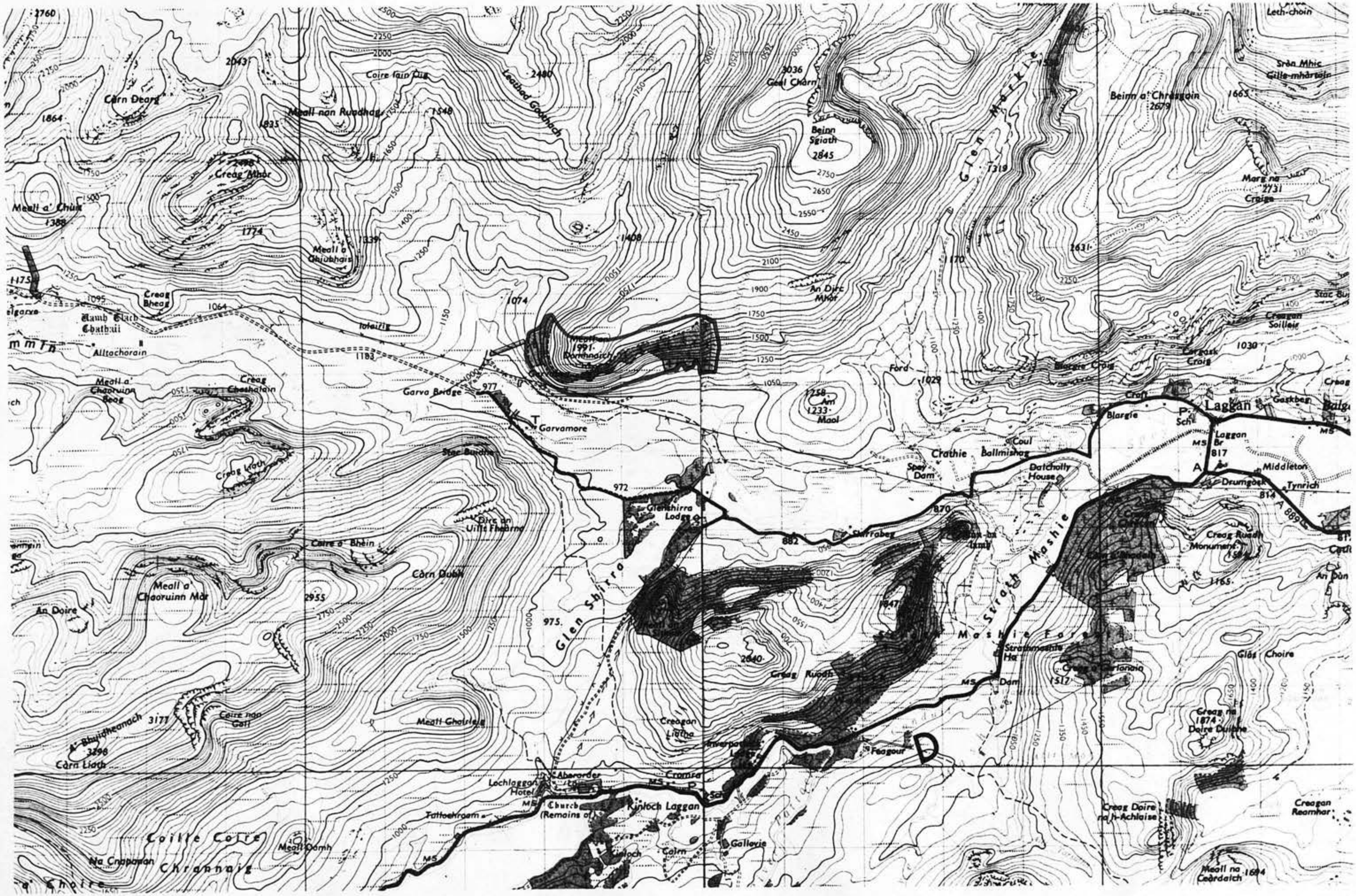
5. Topography. The main physical features of the region are the glaciated hills which slope steeply down to a valley through which the River Spey flows from west-north-west to east-south-east.

The site itself is on the lower slopes of a spur of Geal Charn, which rises to 3,036 feet to the north-east and is part of the Monadhliath Range. The contours run approximately east - west but at the west end of the area curve round to run north - south. Slopes are generally very steep and become precipitous in many places. In the east burns flow through moderately deep gorges.

The ground in the western third is very irregular due

Locality Map for Meall an Domhnaich

Scale 1" = 1 Mile (Extracts from Ord. Survey Sheets 36 & 37)



to the presence of huge boulders and blocks of rock. A gradual change takes place towards the east as the ground becomes flatter, and there is generally a deeper covering of soil.

Aspects vary from south in the eastern half changing to south-west and west to become north-west at the western edge of the area.

6. <u>Climate</u>. (i) Climatic zone. The site lies in the B3a climatic sub-region for which the meteorological data is as follows:

Mean range of temp. °F	Mean min. temp. °F	Days of frost	SUNSHINE June. Mean hrs/day	SUNSHINE Year %	Growing season rainfall. ins.
25	34.5	50-100	5.0-6.5	23	20-30

(ii) Rainfall. Measurements are recorded at the Spey Dam, two miles to the east of the area.

Mean monthly rainfall for period 1957-61; inches.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
4.6	3.5	2.4	2.6	2.1	2.1	3.5	4.2	3.3	5.5	2.9	5.7	42.4

(Rainfall histogram as for previous site.)

From March to June the rainfall is more or less constant at 2" per month. The driest months are May and June and the wettest is December.

(iii) Snowfall. There are no figures available for this area but data for Dalwhinnie, 15 miles to the south-east, can be used as a guide. This meteorological station is at an elevation of 1,176 feet, about 300 feet lower than the working area.

No. of days of snow lying at 0900 hrs. at Dalwhinnie.
5-year av. 1956-60.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
13	12	5	1	0	0	0	0	0	0	2	4	37

(iv) Temperature. As there are no recorded temperatures for this district, those for the Dalwhinnie meteorological station have been used to which a correction of -1°F has been applied for every 300 feet increase in altitude, taking the altitude of Dalwhinnie as 1,200 feet and that of Meall an Domhnaich as 1,500 feet.

Mean monthly temp. in °F for 5-year period 1956-60.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
30.5	31.2	36.9	40.6	44.6 *	51.0	52.7	52.2	49.1 +	45.2 +	38.7 *	34.2

* = 3-year average
\+ = 4-year average

(v) Frost. Data for the climatic sub-region indicates that 50 to 100 days of frost can be expected per year.

(vi) Wind. The prevailing wind is west-south-west though easterly winds, according to local inhabitants, seem to have increased in frequency during the last few years.

(vii) Growing season: for tree growth - 133 days;
for grass growth - 187 days.

Growing season rainfall can be assessed from the histogram and data on page 269 and is approximately 21 inches.

7. Exposure. The eastern half is very exposed to the east and south but there is some geomorphic shelter to the north. On the west of the site exposure is high to the

south, west, north-west and north.

The surrounding hills are in the region of 3,000 feet and probably provide some geomorphic shelter for the site, particularly Geal Charn (3,036 feet) and Beinn Sgiath (2,845 feet) to the north-east.

8. Geology. (i) Solid. The rocks are metamorphic and are a mixture of quartzose-mica-schists, mica-schists and fine- to coarse-grained gneisses. The bedrock is near the surface and outcrops frequently, while in the centre of the site there are extensive crags where the strata dip almost vertically.

(ii) Drift. The general direction of ice movement in this region was from west to east.

On the west of the ridge of Meall an Domhnaich the drift material is predominantly composed of large, angular blocks of rock while to the east of this ridge it is of finer, angular stones and confined mainly to the middle and lower slopes. There is little drift material on the upper slopes as where the bedrock is not exposed it is either covered by peat or a thin layer of soil which has formed *in situ* through weathering.

9. Soils. Soils are thinner in the west, varying from nothing to about $1\frac{1}{2}$ feet in the pockets between the large boulders. In the centre of the site where the crags occur the soil is thin but tree roots can probably penetrate down the vertical cleavage planes in the rock.

The eastern part has deeper soils and poorer drainage, resulting in gleying, and where drainage is very poor a shallow layer of peat has formed.

(i) Brown earth. This type is confined mainly to the western half of the site where drainage is good, but there are also small patches in the gleyed brown earth type wherever drainage is locally good.

Description of soil profile

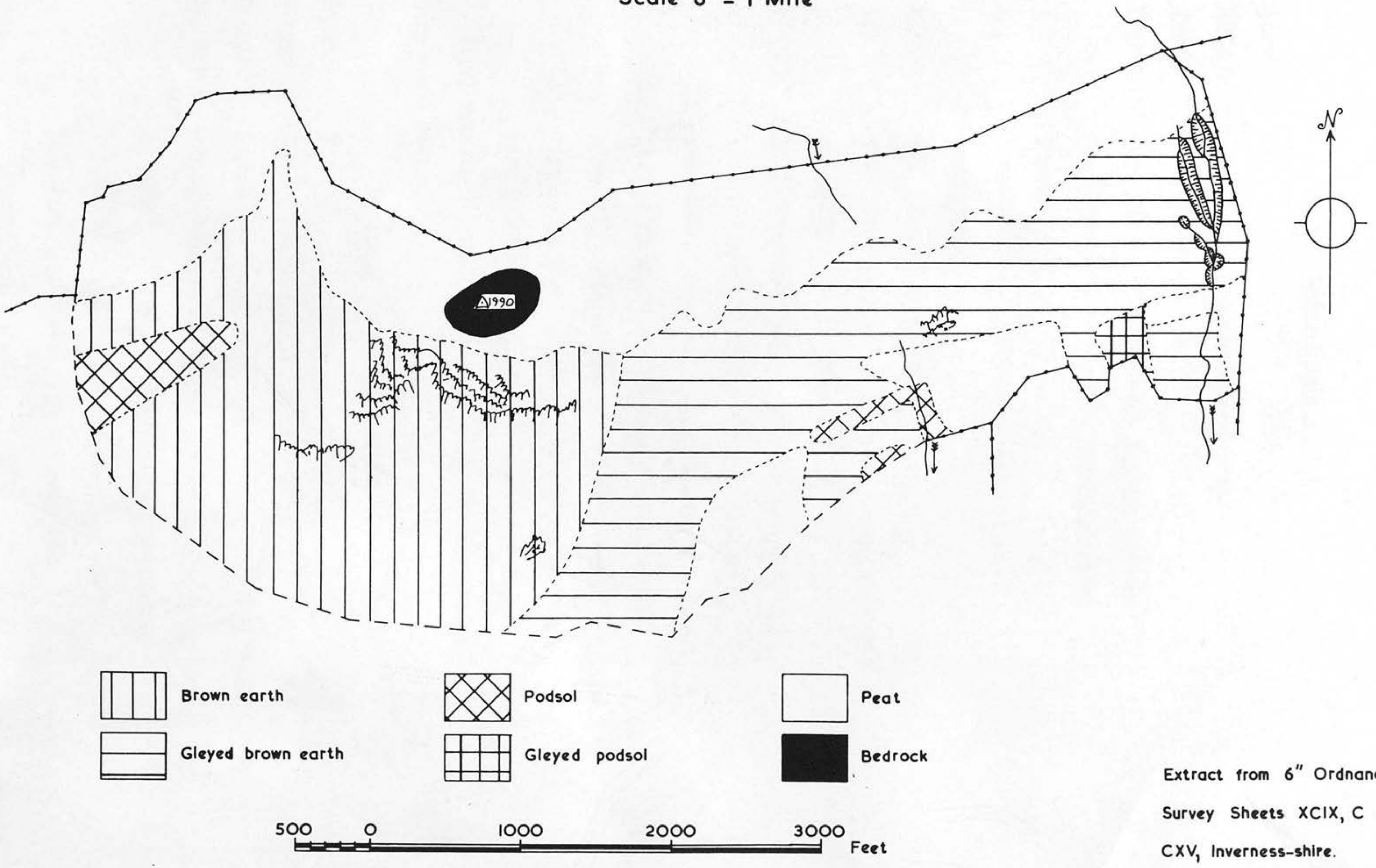
Aspect:	S
Slope:	Very steep (middle slopes).
Vegetation:	*Festuca* species (a, c-d), *Agrostis* species (a, c-d), *Rhytidiadelphus squarrosus* (a, s-d).
A_{oo}	Thin layer of grass leaves not felted together.
A_oF	$\frac{1}{4}$". Decaying grass leaves.
A_oH	Indistinguishable.
A	3". Chocolate brown colour; small crumb structure; predominantly gravelly texture, containing small, angular stones. Rooting throughout horizon but no sign of worm activity.
B	A horizon gradually merges into B horizon, which is darker brown in colour. 6". Structureless owing to large number of small, angular stones. Rooting throughout. No worm activity.
C	Bedrock.

(ii) Gleyed brown earth. Deeper soils and less steep slopes in the eastern half probably result in a slower run-off of moisture, accounting for the gleying.

Meall an Domhnaich

Soil Map

Scale 6" = 1 Mile



Extract from 6" Ordnance Survey Sheets XCIX, C & CXV, Inverness-shire.

Description of soil profile

Aspect: SSE

Slope: Very steep (upper middle-slopes).

Stand: Pure European larch.

Vegetation: *Agrostis* species (a, c-d), *Festuca* species (a, c-d), Wood sorrel (f), *Rhytidiadelphus squarrosus* (f).

A_{oo} Remains of grass leaves, mosses and larch needles.

A_oF $\frac{1}{2}$". Loose and brown in colour.

A_oH 3". Fine, granular black mull humus, merging gradually into next horizon.

A 3". Greyish-brown colour, streaked with black humus. Sandy texture with small crumb structure. Worms absent. Rooting throughout.

B_g 5". Gley horizon. Grey colour with yellow streaks. 'Water table' below this depth. Texture is a clayey-sand, small-block structure, with rooting taking place to $11\frac{1}{2}$ to 12 inches.

(iii) Podsol. This is confined to areas under Scots pine where drainage is good.

Description of soil profile

Aspect: W

Slope: Steep (middle slopes).

Stand: Pure Scots pine.

Vegetation: *Rhytidiadelphus squarrosus* (a, c-d), *Pleurozium schreberi* (a, c-d), *Rhytidiadelphus triquetrus* (f), *Hylocomium splendens* (f), *Festuca* species (f), *Agrostis* species (f), Bilberry (o).

A_{oo} Very thin layer of loose pine needles, twigs and cones and remains of grasses and mosses.

A_oF 6". Very dark brown fibrous material.

A_oH 3". Black, amorphous, greasy mor humus.

A_1 1". Black horizon, containing humus, with some bleached sand grains. Sandy texture; structureless. Worms absent. Rooting throughout.

A_2 2". Grey-white leached layer of sandy texture; structureless. Rooting throughout and no sign of worms.

B_1 2". Dark brown, sandy-gravelly texture. Slight induration but penetrable by roots. Structureless; worms absent.

B_2 Av. 6", but very variable, depending on microtopography. Yellow-brown colour, sandy-gravelly texture; structureless. Rooting takes place into this horizon. Worms absent.

C Bedrock.

(iv) Gleyed podsol. Only one small area of this type occurs in the east of the site under Scots pine, where drainage is locally poor.

Description of soil profile.

Aspect: S

Slope: Gentle (lower slopes).

Stand: Pure Scots pine.

Vegetation: *Molinia* (d & a), *Pleurozium schreberi* (f).

A_{oo} Remains of pine needles and *Molinia* leaves felted together.

A_oF 3". Dark brown, fibrous and felted, with plant remains distinctly visible.

A_oH 1". Black; crumbly texture.

A_1 2". Black. Very few bleached sand grains. Sandy with some clay. Very fine crumb structure. Rooting throughout; worms absent.

A_2 1". Brownish-white leached layer. Sandy texture with some clay and very fine crumb structure. Rooting throughout; worms absent.

B_g 18". Ochre brown colour with yellow-brown streaks. Sandy-gravelly texture; structureless. Worms absent. Rooting down to 12" in this horizon.

(v) Peat. Along the western and northern part of the site the peat lies directly on the bedrock, while on the lower ground in the east it overlies mineral soil where drainage is poor.

10. Drainage. Steep slopes and generally thin soils contribute to good drainage in the western half of the site. In the east, however, soils are deeper and slopes less steep, resulting in slower drainage. On gentle slopes drainage is very poor as the impervious bedrock prevents the water from percolating downwards, resulting in waterlogged conditions and peat formation.

11. Vegetation. The area is dominantly *Festuca/Agrostis* grassland.

(1) Festuca/Agrostis

Sheep's fescue, d & a.
Red fescue, f.
Festuca vivipara (L.) Sm., o.
Agrostis canina, d & a.
Common bent, a.
Sweet vernal, f - la.
Tufted Hair-grass, lf.
Wavy Hair-grass, lf.
Yorkshire fog, o - la.

Heath bedstraw, a.
Viola species, f - la.
Tormentil, f.
Wood sorrel, lf.
Foxglove, lf.
Ranunculus species, lf.
Carduus species, lf.
Self-heal, o.
Harebell (*Campanula rotundifolia* L.), o.

Bracken, lf - la.
Hard fern (*Blechnum spicant* (L.) Roth), f.

Soft rush, lf.
Heath rush, lf.

Hylocomium splendens, la.
Rhytidiadelphus squarrosus, la.
Thuidium tamariscinum, lf.
Polytrichum commune, lf.
Green sphagnum, o.

(2) Festuca/Agrostis/D. caespitosa

Sheep's fescue, a, c-d.
Agrostis canina, a, c-d.
Tufted Hair-grass, a, c-d.
Yorkshire fog, la.
Red fescue, lf.
Wavy Hair-grass, lf.
Purple Moor-grass, lf.

Ranunculus species, f - la.

Soft rush, f.

Hylocomium splendens, la.
Rhytidiadelphus triquetrus, lf.

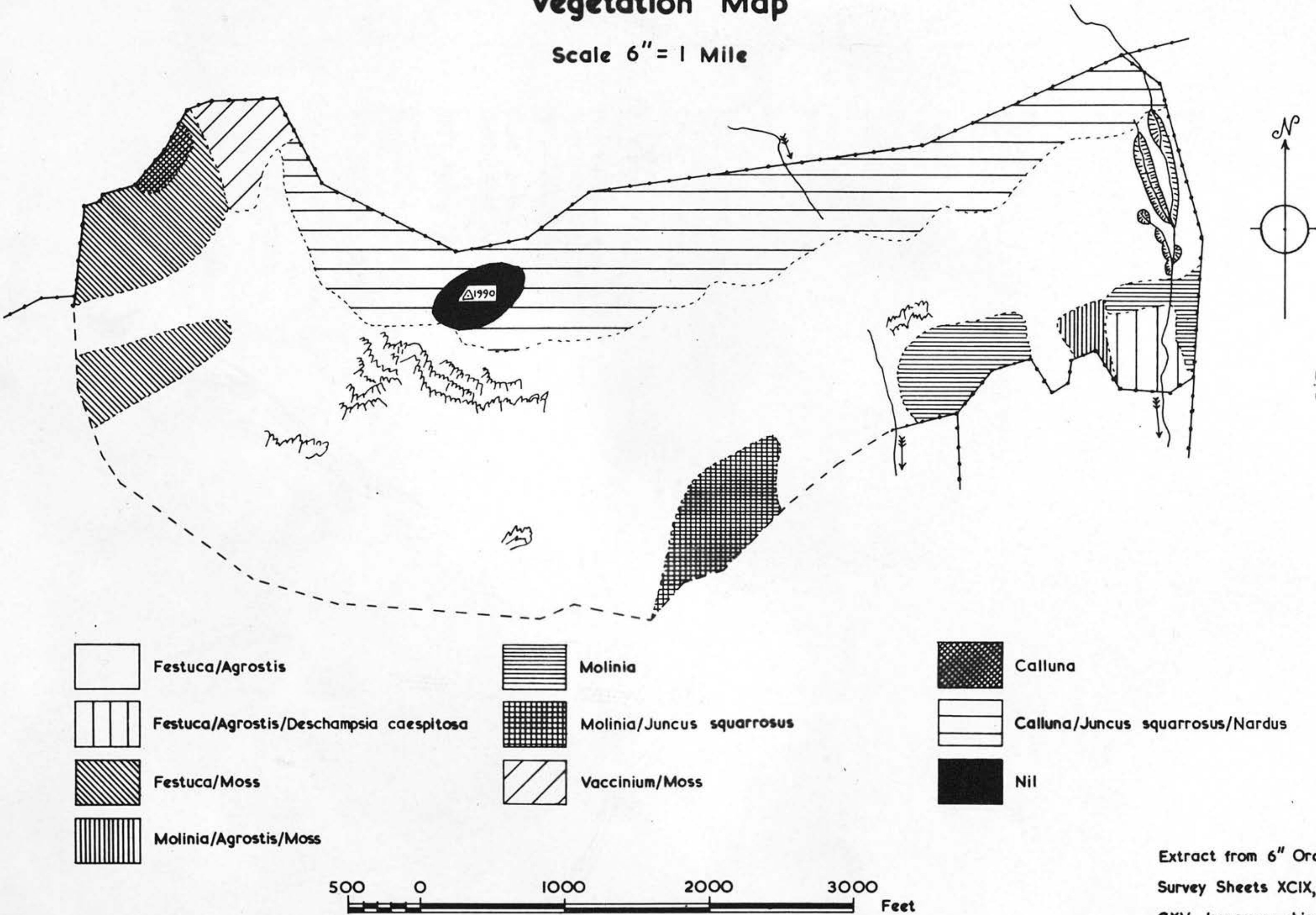
(3) Festuca/Moss.

Sheep's fescue, a, c-d.
Pleurozium schreberi, a, c-d.
Rhytidiadelphus triquetrus, a, s-d.

Meall an Domhnaich

Vegetation Map

Scale 6" = 1 Mile



Extract from 6" Ordnance Survey Sheets XCIX, C & CXV, Inverness-shire.

Wavy Hair-grass, lf.
Agrostis canina, o.

Wood sorrel, f.
Tormentil, f.
Hard fern, f.
Bilberry, o.
Luzula species, o.

(4) Molinia/Agrostis/Moss.

Purple Moor-grass, a, c-d.
Agrostis canina, a, c-d.
Hylocomium splendens, a, c-d.

Yorkshire fog, la.
Tufted Hair-grass, lf.
Wavy Hair-grass, lf.
Festuca vivipara, o.

Tormentil, f.
Bracken, lf.

Soft rush, lf.

Polytrichum commune, lf - la.
Pseudoscleropodium purum, f.
Green sphagnum, lf.

(5) Molinia.

Purple Moor-grass, d & a.
Yorkshire fog, a,
Agrostis canina, f.

Wood sorrel, f.
Ranunculus species, f.

Soft rush, lf.

Hylocomium splendens, f.
Green sphagnum, f.
Polytrichum commune, lf.

(6) Molinia/Juncus squarrosus.

Purple Moor-grass, a, c-d.
Heath rush, a, c-d.

Tufted Hair-grass, lf.
Yorkshire fog, lf.
Sweet vernal, o.

Ranunculus species, lf.
Tormentil, o.
Carduus species, o.

Green sphagnum, f.
Hylocomium splendens, lf.
Polytrichum commune, lf.

(7) Vaccinium/Moss.

Bilberry, a, c-d.
Pleurozium schreberi, a, c-d.

Cowberry (Vaccinium vitis-idaea L.), f.
Crowberry (Empetrum nigrum L.), f.
Heather, lf.

Polytrichum commune, f.
Green sphagnum, lf.
Hylocomium splendens, lf.

(8) Calluna

Heather, d & a.
Bilberry, f.
Cowberry, f.
Crowberry, f.

Heath rush, f.

Pleurozium schreberi, lf.
Hylocomium splendens, lf.
Pseudoscleropodium purum, lf.
Green sphagnum, lf.

(9) Calluna/Juncus squarrosus/Nardus.

Heather, la - a, c-d.
Heath rush, a, c-d.
Mat-grass, la, c-d.

Purple Moor-grass, la.
Tufted Hair-grass, lf.
Wavy Hair-grass, lf.
Sheep's fescue, lf.
Sweet vernal, o.

Tormentil, f.
Ranunculus species, f.
Cross-leaved Heath (Erica tetralix L.), o.
Lousewort (Pedicularis palustris L.), o.
Heath milkwort, o.
Germander speedwell, o.

Hard fern, o.

Green sphagnum, a.
Polytrichum commune, lf.
Pseudoscleropodium purum, lf.

Vegetation type	Acreage	Acreage as % of total area
1. Festuca/Agrostis	272.4	63
2. Festuca/Agrostis/D. caespitosa	6.3	1
3. Festuca/Moss	24.3	5½
4. Molinia/Agrostis/Moss	2.5	½
5. Molinia	13.3	3
6. Molinia/Juncus squarrosus	11.7	3
7. Vaccinium/Moss	7.3	2
8. Calluna	1.1	-
9. Calluna/Juncus squarrosus/Nardus	89.2	21
10. Nil	4.7	1

12. Harmful influences. Exposure is probably the limiting factor for tree growth on the higher ground. The tree line is about 1,700 feet in the east, decreasing to approximately 1,500 feet in the west.

Windblow has occurred in the east in stands on the poorly-drained areas.

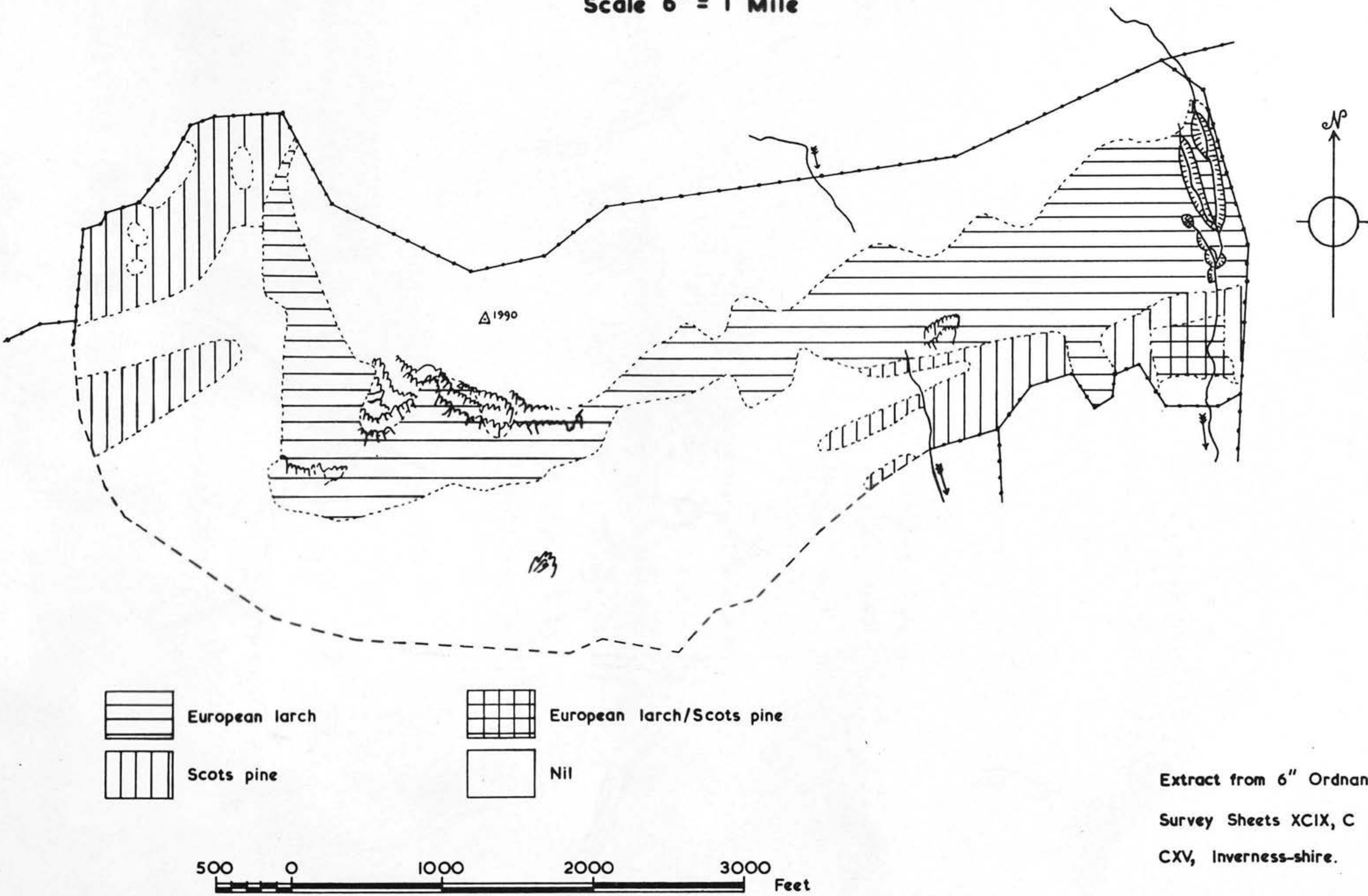
13. Use of surrounding land. In the immediate vicinity rough grazing is the only land use, but tree planting is taking place on some of the surrounding hills and low ground. In the valley much of the land is arable, though some is devoted to forestry.

14. Communications. Access to the site is bad, as the River Spey lies between it and the only road in the vicinity. A farm track is within ¼ mile of the southern boundary at the western edge and there is a bridge over the river ¾ mile to the south of the eastern edge of the site but the intervening ground is soft peat.

Meall an Domhnaich

Stand Map

Scale 6"= 1 Mile



Extract from 6" Ordnance Survey Sheets XCIX, C & CXV, Inverness-shire.

B. STAND

1. Species. Most of the site is occupied by pure European larch, growing on the middle and upper slopes and extending to the tree line. Pure Scots pine occurs in four main blocks on the middle and lower slopes and a small block of European larch/Scots pine mixture in the south-east corner of the site (Plates 11 and 82-84).

2. Structure. The whole plantation is single-storied, even-aged high forest.

3. Height. The average height of the Scots pine is 55 feet, varying from 52-61 feet in the west, and 44-65 feet in the east. The larch varies from 40 to 78 feet, the average being 61 feet.

4. Canopy. The Scots pine in the west has a 100% canopy in most places, though windblow has reduced this occasionally to 80%. In the east, however, 85-90% is general for this species. The canopy of larch, in all but the eastern third where thinning is in progress, is 85-90%, decreasing to 60% near the tree line. After thinning there is a 50% canopy.

5. Origin, age and development stage. There are no records for this plantation but ring counts indicate that the Scots pine is between 75-80 years old and the larch 67-70.

Both species are in the medium to large timber stage, except for the larch on the top slopes which is in the medium to large pole stage.

6. Form and condition. The larch is of good form, with

Plate 82. Eastern third of Meall an Domhnaich, looking north-east. River Spey in middle-ground.

Plate 83. Looking east from the top of Meall an Domhnaich.

light branching and straight stems. Health is good, except in areas of poor drainage and near the tree line where exposure has retarded growth.

The Scots pine, on the other hand, is coarsely and heavily branched. In the west it is healthy, though windblow has occurred, but in the east where the soil has become waterlogged most of the trees are dying and extensive windblow has occurred.

7. Natural regeneration. Absent.

8. Stocking and volume.

Stand type	Species	Av. top ht. ft.	No./acre	B.A./acre H.ft.O.B.	Vol./acre H.ft.O.B.
E. larch	E. larch	61	210	102	2,790
Scots pine	(2 blocks at W end)	57	435	147	3,620
	Remainder	54	286	161	3,700
E. larch/ Scots pine mixture	E. larch	61	71	36	950
	Scots pine	62	93	44	1,200

9. Acreage.
- (i) Total . . . . 432.8 acres
- (ii) Present productive . . . 161.7 "
  - European larch . . . 109.5 "
  - Scots pine . . . . . 47.8 "
  - Larch/Pine mixture . 4.4 "
- (iii) Present unproductive . . 271.1 "
- (iv) Potentially productive . 424.4 "

C. PAST AND PRESENT TREATMENT

1. Forestry. On the 1899 edition of the 6" Ordnance Survey map the whole of the site, except for the exposed rock on the highest ground, is shown as coniferous forest. There is now no sign of there having been any trees above the present tree line and it is likely that this area was

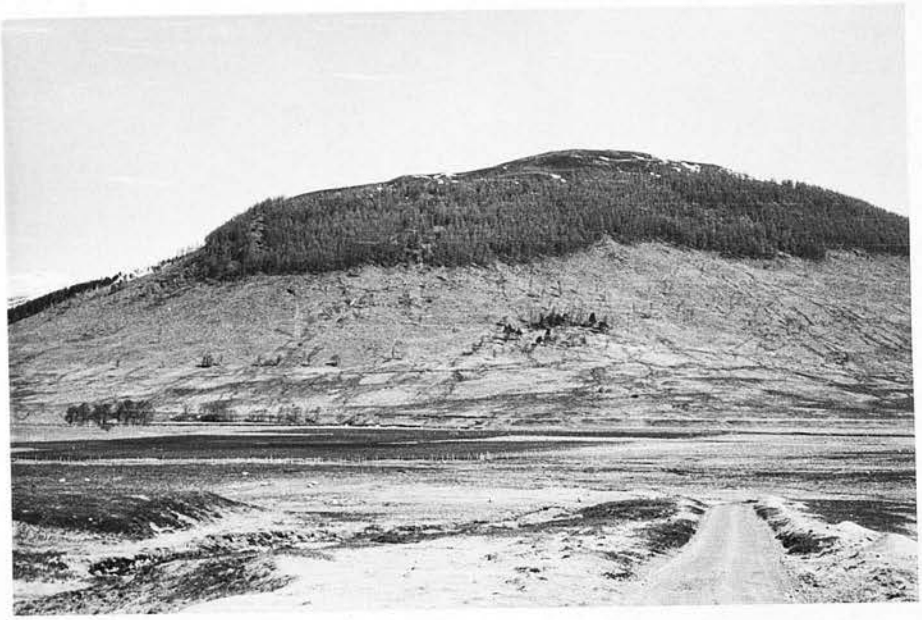


Plate 84. Looking north towards Meall an Domhnaich. Note the gradual depression of the tree line from right to left and the felled area below the larch.

(NOTE: Plate 11, looking north-east, shows the triangular block of Scots pine in the west of the site.)

too exposed for tree growth and the plants died while still young. The Scots pine are on average 10 years older than the larch, which suggests that the lower and more accessible ground was planted first.

During the last war most of the timber on the lower slopes was cut down, leaving the plantation in its present state.

Thinning is in progress in the eastern part of the site and will continue westwards. This appears to be the second thinning within the last 15 years, while in the remaining area there is evidence of only one thinning having taken place within this time.

2. Grazing. (i) Season of use. The site is accessible to livestock throughout the year but is used mainly from the beginning of December to the end of May.

(ii) Type of stock. Blackface sheep and red deer.

(iii) Stocking. 500 to 600 Blackface ewes have access to the plantation and if all (600) use the tree shelter at one time this would create a stocking rate of nearly 4 sheep to the acre.

(iv) Condition of vegetation. The larch has a marked beneficial effect on the vegetation. Within the stand there is a good Festuca/Agrostis sward while on the treeless middle and lower slopes of similar soil type the grass is less dense. On this predominantly southerly aspect it may be due to the drying out of the shallow soils in summer, resulting in the death of many plants, while under the shade of the larch the soil is protected from dessication.

The pine in the west is dense and there is only a light covering of Festuca grasses. In the east, however, it is more open but the soil is poorly drained and Molinia dominates most of these areas. Drainage could probably achieve an improvement of the vegetation for grazing.

Bracken is present on some parts of the hill, mainly on the treeless middle and lower slopes and less frequently within the larch stand. Measures to control this weed now, while it is not widespread, would be worthwhile.

(v) Water. There are several streams and springs in the working area which are accessible to stock.

(vi) Damage to the stand. No damage to the trees was observed.

D. POSSIBLE FUTURE TREATMENT

1. Controlling factors.

(i) Objects of management:

(1) the maximum commercial production of timber consistent with good silvicultural practice, with the locality factors, especially soil and elevation, dictating the choice of species, and

(2) the integration of forestry and agriculture wherever possible.

(ii) Requirements for out-wintering. Shelter for sheep and deer and sheltered grazing for the production of early spring grass are the main requirements from this site.

(iii) Site. Steep, boulder-strewn slopes with soft peat land on the low ground make the site relatively inaccessible to machinery and unsuitable for improvement of vegetation, and it is too far from the Home Farm for out-wintering cattle. This limits the use to sheep, which are not hand fed in winter, and deer. The shelter is of considerable value for two reasons: (a) it is on high ground, and in times of storm the animals do not have to come down to low ground for shelter and then trek up to the high ground again in fine weather, and (b) there is little other shelter in this area which is accessible to livestock.

2. Sylvo-pastoral objective.

It is considered that a coniferous plantation will fulfil the objects of management and satisfy the requirements for out-wintering.

European larch should be the main species and form the matrix of the stands with dense-canopied conifers planted in blocks throughout this matrix, so that a "patchwork" effect is produced. In this way it is considered that sheltered grazing will be obtainable under the larch due to its light canopy, while the dense-canopied conifers will provide the shelter for stock. For the latter, Sitka spruce should be used in the moist hollows, Scots pine in dry, exposed situations, Pinus contorta as a nurse species on the high ground above the present tree line, and Western Red Cedar (Thuia plicata D. Don.) on the middle and lower slopes. Western Hemlock (Tsuga heterophylla Sarg.) and Abies species, probably Abies procera Rehd., should also be tried in suitable situations. Mountain pine will probably be the only species capable of growing on the very exposed top slopes in the north-west of the site.

The Group Shelterwood silvicultural system (as distinct from the Group Selection system), with artifical regeneration, is recommended for this plantation. This seems desirable as only a relatively short regeneration period would be required and a more or less even-aged stand is produced. A Selection system is impracticable because there would always be young growth vulnerable to browsing and the Uniform system, which is a possible alternative, has no advantages over the Group system if artificial regeneration is employed. Clear-felling is considered unsuitable as the area is exposed and once a forest microclimate has been created this should be maintained so that conditions for the establishment of future tree growth are favourable.

3. Short term treatment (next 5 years).

Initial treatment should be concerned with drainage operations. In the east of the site water flows continually down the slopes from higher ground and many cut-off drainage channels are required. These should be led into the streams.

The plantation will have to be divided into compartments for the purposes of forest management and it is suggested that these be about 25-30 acres in extent, demarcated by posts in the ground.

Planting in the first 5-year period should be confined to the bare areas, concentrating particularly on the top slopes above the tree line, as the chances of successful establishment at present are good, due to the shelter afforded by the larch. Deer fencing will be necessary round these areas until they are out of danger from browsing.

4. Long term treatment.

After successful establishment of the first planting, and removal of the fences, regeneration should continue on the bare areas until they have been reafforested. During this period thinnings should take place normally throughout the remainder of the plantation.

It is suggested that the regeneration of the present tree-covered area should proceed in the following manner. Compartments in urgent need of regeneration should be determined and in these any gaps in the stand should be planted first. Thereafter, gaps should be created artificially and planted up, with the old trees surrounding the gaps being felled gradually to make way for new planting. Thus regeneration will proceed outwards from each gap, until the intervening trees have all been removed and the groups of regeneration meet. The resultant stands will be uneven-aged at first but will probably become even-aged by the time the pole stage is reached.

To protect the young growth from sheep and deer it is suggested that polythene or nylon netting be tied to the peripheral trees of the compartments undergoing regeneration. These trees must be left standing until the majority of the young growth no longer needs protection, whereupon the netting can be removed and the trees felled away from the regeneration into the older stands. When this stage has been reached further compartments are allocated for regeneration and the procedure repeated.

SITE 6

TENTSMUIR FOREST

A. SITE

1. Location. Tentsmuir Forest is situated on the east coast of the county of Fife, north of St. Andrews, and between the estuaries of the Rivers Tay and Eden. It extends into two parishes, Ferry Port on Craig in the north and Leuchars in the south.

The working area comprises two sections of the forest, about a mile apart, the intervening area being rough grazing land.

The northern section is made up of 2½ compartments of the main forest, compartments 70, 71 and half of compartment 72. The 1" Ordnance Survey map reference is 479228.

The southern section is an outlier of the forest and is known locally as "Rireas". The 1" Ordnance Survey map reference is 485214.

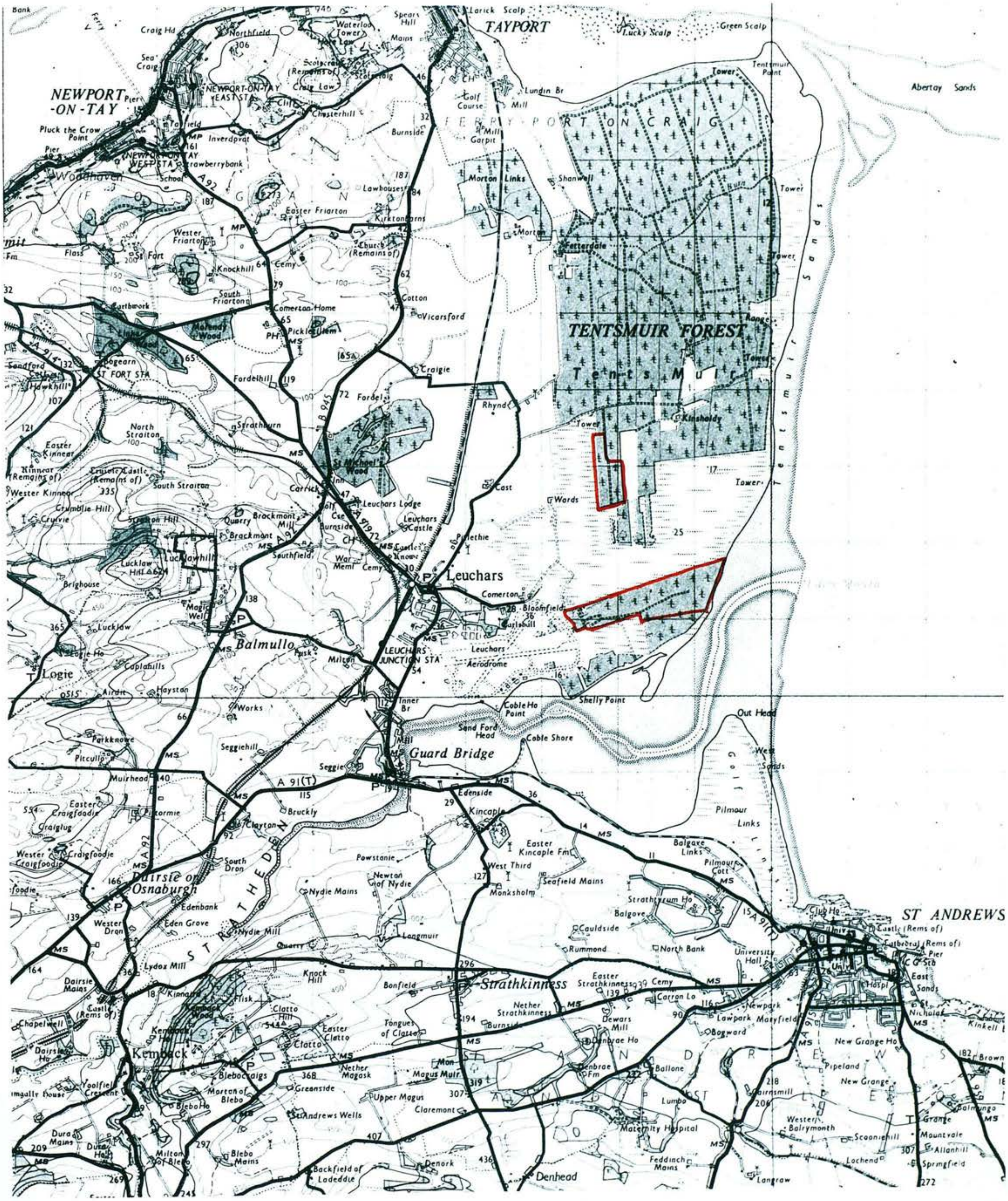
2. Estate and owner. Both sections of the working area are owned by the Forestry Commission and the grazing is leased to a local farmer.

3. Boundaries. The northern section is L-shaped and all the boundaries are demarcated by post-and-wire fences, except in the north of compartment 70 and the east of compartment 72, which are delimited by fenced forest rides. Internal boundaries are forest rides with compartment numbers stencilled in white paint on corner trees.

The southern section is long and narrow in shape and

Locality Map for Tentsmuir Forest

Scale 1" = 1 Mile (Extract from Ord. Survey Sheet 56)



orientated in an east-south-east - west-south-west direction. All external boundaries are clearly demarcated with post-and-wire fences and internal boundaries are forest rides.

4. Altitude. The variation in altitude is very small, the highest ground being little more than 25 feet with the lowest about 12 feet above sea level.

The surrounding land is also flat. 2 miles to the west the ground rises to between 200-300 feet and the nearest hill is Lucklaw Hill (624 feet), $3\frac{1}{2}$ miles to the south-west.

5. Topography. The area is flat, with sand dunes adjacent to the high water line.

6. Climate. The data in this section was recorded at Leuchars meteorological station which is situated immediately to the west of the forest on the south bank of the Tay estuary.

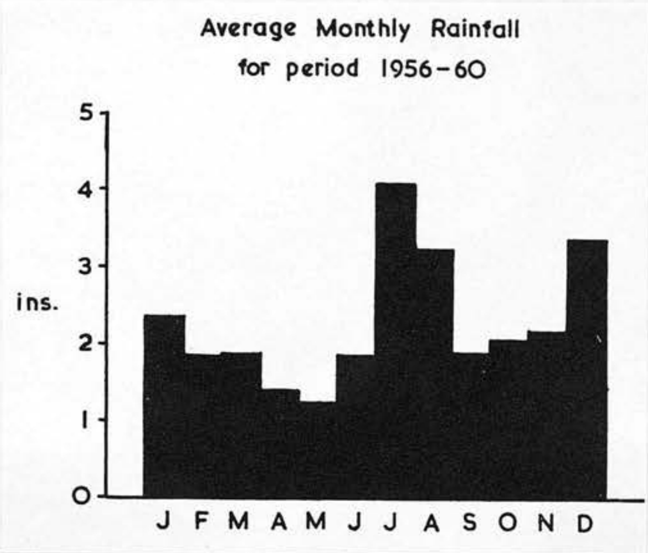
(i) Climatic zone. The area is in climatic sub-region Blb.

Sub-region	Mean range of temp. °F	Mean min. temp. °F	SUNSHINE June. Mean hrs/day.	SUNSHINE Year %
Blb	27	34	6.25	31

(ii) Rainfall.

Mean monthly rainfall for period 1956-60; ins.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
2.4	1.9	1.9	1.4	1.2	1.9	4.1	3.2	1.9	2.1	2.2	3.4	27.5



July is the wettest and May the driest month of the year.

(iii) Snowfall. Snow is infrequent, and when it falls it does not lie for long.

Av. no. of days with snow lying at 0900 hrs.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
4	6	1	0	0	0	0	0	0	0	0	0	11

(iv) Temperature.

Av. temps. for 5-year period 1956-60; °F.

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly	36.9	37.6	41.7	46.1	50.6	55.3	58.4	57.4	55.0	50.4	43.5	39.7
Mean monthly minima	32.4	32.4	37.2	39.3	43.4	48.6	51.9	51.2	48.9	45.0	38.4	35.7

The temperature rises from a minimum in January to a maximum in July.

(v) Frost.

Av. no. of days with ground frost for period 1956-60.

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
19	17	8	7	3	0	0	0	0	1	10	14	79

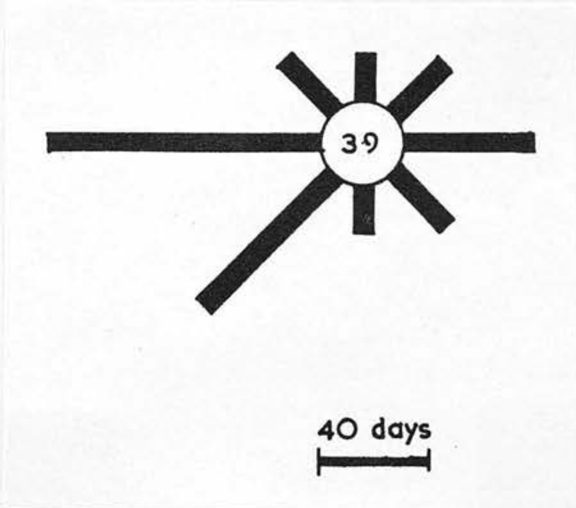
June to September is generally frost free and the maximum number of days of ground frost occur in January.

(vi) Wind. The following wind data is for 0900 hours. This time was selected from the four available (0300, 0900, 1500 and 2100) because although the wind speed reaches its maximum velocity later in the day, it was considered that the lower temperatures existing at this time would present more rigorous conditions for livestock. In addition, 0900 hours is the general standard time for most meteorological observations and thus the wind data can be related with the other climatic information in this section.

Period 1956-60

	Av. no. of obs. on which wind was:									Av. no. of obs. on which wind exceeded 12 mph (10 kts, Beaufort 3)
	N	NE	E	SE	S	SW	W	NW	Calm	
Jan.	2	0	1	2	1	6	12	3	4	9
Feb.	2	1	2	1	1	5	8	3	5	7
Mar.	1	2	7	5	2	4	4	1	5	11
Apr.	3	1	3	1	2	6	9	3	2	9
May	1	3	7	2	1	5	7	3	2	10
Jun.	1	4	7	3	1	4	8	1	1	8
Jul.	1	5	4	2	1	6	7	3	2	8
Aug.	2	4	4	2	1	4	8	3	3	8
Sept	1	3	4	2	2	4	8	3	3	10
Oct.	1	1	4	1	1	9	9	2	3	13
Nov.	1	1	1	2	2	6	10	1	6	7
Dec.	1	1	2	3	2	8	10	1	3.	12
Total	17	26	46	26	17	67	100	27	39	112

From the above table it is clear that the prevailing wind is westerly. After this, south-westerly winds are most frequent, as shown in the following wind rose diagram. The figure in the circle is the number of days of calm.



During March, May and June easterly winds are frequent. North, north-east and east winds occur on average on 89 days per year, south-east and south on 43 and south-west, west and north-west on 194. For almost one third of the year winds are in excess of 12 m.p.h.

(vii) Growing season. The growing season for trees is 226 days, extending from the beginning of April to about the beginning of November. For grass it is 245 days, starting in mid-March and ending approximately in mid-November.

8. Geology. (i) Solid. Blown sand is the parent material for all soils in this area.

(ii) Drift. Ice flow was in a north-west to south-east direction and at that time the area was probably beneath the sea. Being between the two estuaries of the Tay and Eden, it is likely that much of the drift material is of fluvio-glacial origin, though marine action has subsequently modified this.

9. Soils. The whole forest is covered by a podsol of sandy texture except for a small area of peat in compartment 70. Fertility is generally low but the presence of Rosebay willow herb and stinging nettles in the grazed areas indicate an adequate supply of nitrogen.

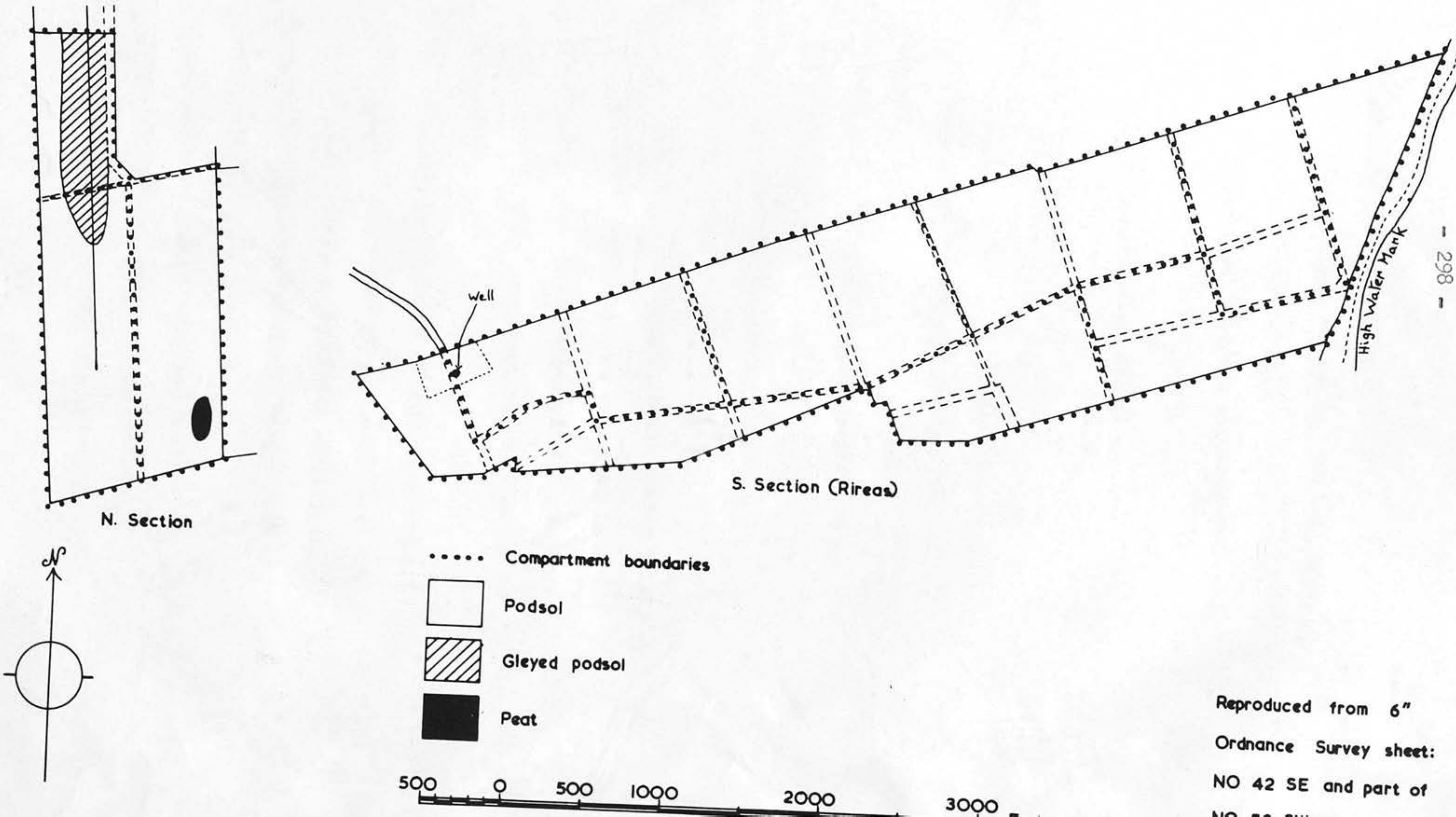
Description of podsol

Slope:	Nil
Stand:	Scots pine, P32.
Vegetation:	Common bent, Creeping bent, Creeping soft-grass, *Pseudoscleropodium purum* and *Pleurozium schreberi*.
A_{oo}	Thin layer of pine needles, cones, twigs, grass and moss remains; not matted together.
A_oF	1". Brown, fibrous, platy structure.
A_oH	$\frac{1}{8}$". Black, amorphous, tending to be crumbly.
A_1	2". Ash-grey layer. Sandy texture and very fine crumb structure. Humus mixing with the mineral soil. Rooting throughout but visible soil fauna absent.
A_2	1". Greyish-white in colour. Sandy texture; structureless. Rooting throughout. Visible soil fauna absent.
B_1	6". Light brown; sandy texture; structureless. Rooting throughout. Visible soil fauna absent.
B_2	2". Dark ochreous colour. Slight induration in this horizon but penetrable by roots. Sandy texture with very fine crumb structure.

Tentsmuir Forest

Soil Map

Scale 6 ins = 1 Mile



Visible soil fauna absent.

C Parent sand. White in colour. Rooting takes place 9" into this material.

The majority of compartment 72 has a gleyed podsol soil type.

Description of gleyed podsol

Slope: Nil

Stand: Scots pine, P30.

Vegetation: Creeping soft-grass (d & a), Reed Canary-grass (la), *Agrostis* and *Festuca* species (f) and male fern (f).

A_{oo} Very thin, consisting of pine needles, twigs and grasses.

A_oF 2". Light brown, mor humus.

A_oH Indistinguishable.

A_1 1". Very dark brown colour, humus mixing with mineral soil. Sandy texture with very fine crumb structure. A few bleached sand grains present. Rooting throughout but no visible soil fauna.

A_2 8". Dark chocolate brown colour, with high humus content but a high proportion of bleached sand grains. Sandy texture with small crumb structure. Rooting throughout but no visible soil fauna.

G Gleyed horizon. Dark brown and whitish streaks present. Sandy texture with small block structure. Rooting takes place 7" into this horizon and the water table is at 38" from the soil surface.

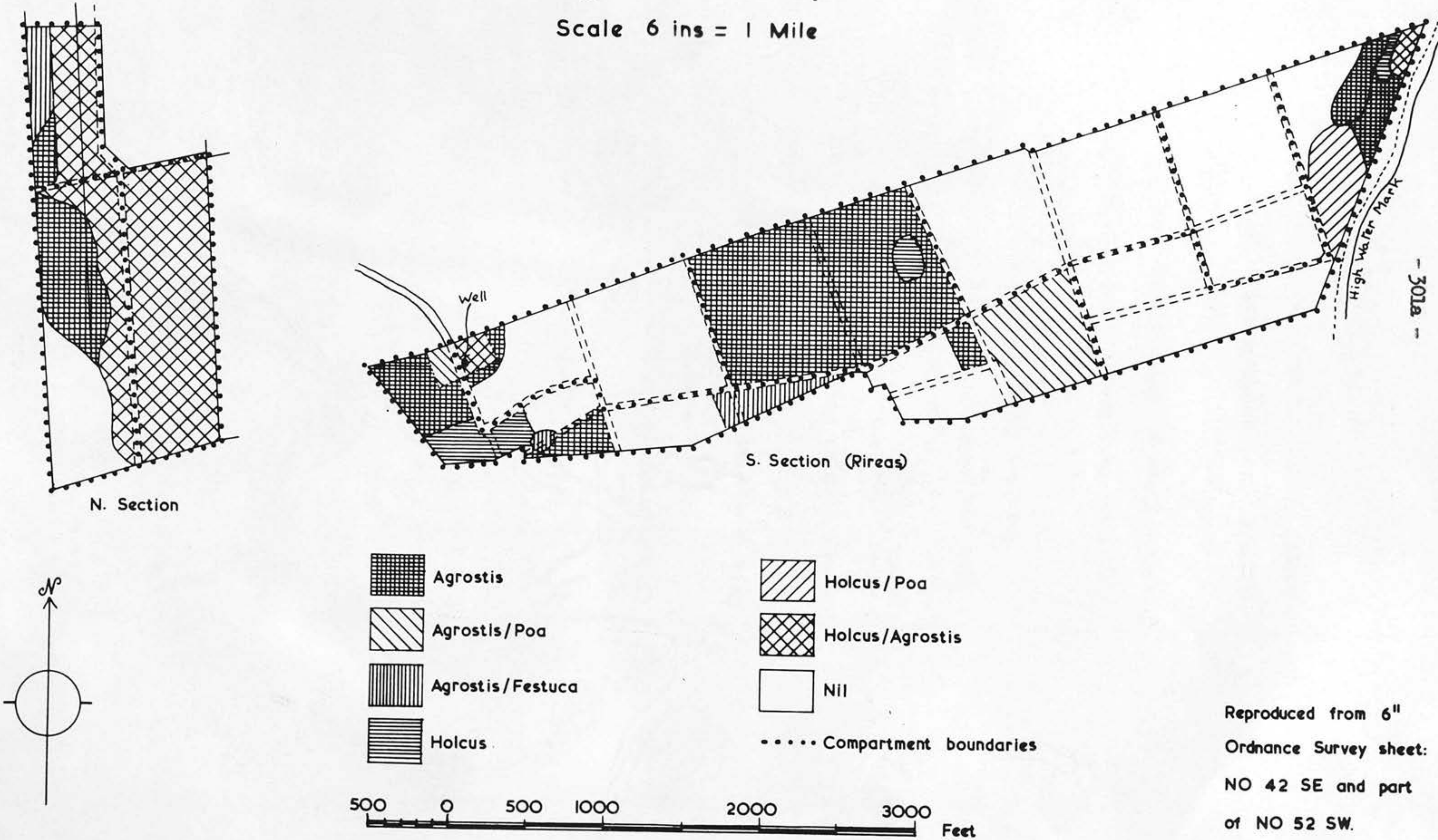
In compartment 70 the soil appears to have been disturbed several times and the podsol is not well-developed and the horizons are thin.

Aspect:	SSW
Slope:	Gentle
Stand:	Scots pine dominant, with frequent Corsican pine.
Vegetation:	Creeping soft-grass (d & a), common bent (a), creeping bent (a), male fern (vf).
A_{oo}	Very thin layer of pine needles of loose structure.
A_oF	$\frac{1}{2}$". Brown, fibrous material.
A_oH	Indistinguishable.
A_2	1". Dark brown but slight leaching taking place. Sandy texture; structureless. Roots throughout. No visible soil fauna.
B_1	$\frac{1}{2}$". Yellowy-brown sand; structureless. Roots throughout and no visible soil fauna.
B_2	2". Light chocolate brown colour. Sandy texture; structureless. Roots throughout. No visible soil fauna.
B_3 ?	12". Buff coloured sand; structureless. Rooting throughout and no visible soil fauna present.
A_2	$1\frac{1}{2}$". Greyish leached layer. Sandy texture; structureless. Rooting throughout. Visible

Tentsmuir Forest

Vegetation Map

Scale 6 ins = 1 Mile



Reproduced from 6"
Ordnance Survey sheet:
NO 42 SE and part
of NO 52 SW.

soil fauna absent.

B 1". Dark ochre-brown colour. Sandy texture; structureless. Rooting throughout. Visible soil fauna absent.

A_2 1". Ash grey leached layer of sandy texture. Structureless. Roots throughout; visible soil fauna absent.

B 1". Dark ochre-brown. Sandy texture; structureless. Rooting throughout but soil fauna absent.

C Yellow sand. Small crumb structure. Free-draining. Visible soil fauna absent. Rooting 6" into this horizon.

This unusual profile has been caused either by blowing sand or flooding.

11. Vegetation. The ground vegetation is predominantly broadleaved, soft grasses.

(1) Agrostis

Common bent, d & a.
Creeping bent, a.
Brown bent (Agrostis canina L. subsp. montana Hartm.) f.

(2) Agrostis/Poa

Common bent, a, c-d.
Smooth-stalked meadow-grass, a, c-d.
Creeping bent, o.
Brown bent, o.

(3) Agrostis/Festuca

Common bent, a, c-d.
Sheep's fescue, a, c-d.

	Acreage	Acreage as % of total area
1. <u>Agrostis</u>	54.2	23
2. <u>Agrostis/Poa</u>	9.3	4
3. <u>Agrostis/Festuca</u>	3.5	1
4. <u>Holcus</u>	4.4	2
5. <u>Holcus/Poa</u>	4.6	2
6. <u>Holcus/Agrostis</u>	42.4	18
7. Nil	122.6	50

(4) Holcus

Yorkshire fog, d & a.
Common bent, o.
Creeping bent, o.
Smooth-stalked Meadow-grass, o.

(5) Holcus/Poa

Yorkshire fog, d & a.
Smooth-stalked Meadow-grass, a, s-d.
Agrostis species, f.

(6) Holcus/Agrostis

Yorkshire fog, d & a.
Common bent, a, s-d.

The following species occur throughout the forest:

Male fern (Dryopteris filix-mas L.), a.
Rose-bay Willow herb (Chamaenerion angustifolium (L.) Scop.), vf.
Heather, lf.
Bracken, lf.
Stinging nettle, lf.
Foxglove, o.
Common violet (Viola riviniana Rchb.), o.
Marsh violet (Viola palustris L.), o.

Reed Canary-grass (Phalaris arundinacea L.) is locally dominant and abundant in a small area about ½ chain wide bordering the edge of compartment 72.

Pleurozium schreberi, f.
Polytrichum commune, f.
Pseudoscleropodium purum, f.
Rhytidiadelphus squarrosus, f.

Addendum, see opposite page.

12. Harmful influences. (i) Insects.

(a) The Pine-shoot moth (Evetria buoliana L.). Many trees in both sections of the working area have suffered from this insect and it is still a pest of the younger trees.

(b) The Pine Looper moth (Bupalus piniaria L.). It is mainly the northern section which is attacked. Yearly counts of the pupae have to be carried out so that if necessary measures can be taken to prevent an epidemic from breaking out. The last count showed a substantial rise in numbers.

(c) The Pine Weevil (Hylobius abietis L.). Seedling mortality is moderately high but it is not caused entirely by this pest. After initial attack by the weevil frost keeps the wounds open, allowing a fungus to become established which finally kills the plant from the point of entry upwards.

(d) The Black pine-beetle (Hylastes ater Payk.). Many of the younger parts of the forest have been damaged.

(ii) Fungi. Fomes annosus is present and all fresh stumps are treated with creosote.

(iii) Climatic agencies.

(a) Frost. Late spring frosts are common and very damaging.

(b) Wind. East winds are destructive because they blow off the sea and carry in salt spray. Browning of the foliage occurs as a result of which it does not kill the tree when young probably checks growth.

As the soil is light and the rainfall low there is the constant danger of soil erosion by wind.

(iv) Fire. The greatest potential danger in this area is fire. There is a public road through the forest to the beach which flanks the forest to the north and east.

13. Use of surrounding land. The main land use is agriculture, with arable predominating.

14. Communications. There are several unmetalled roads leading to the forest and a good system of rides within it. 3 miles to the south-west is Leuchars Junction station, which is on the main Edinburgh-Aberdeen line.

B. STAND

1. Species. Compartments 70-72 are mainly Scots pine, though Corsican pine occurs in mixture in a few small patches. Norway spruce is present in a small area in compartment 70 and holly, birch, hawthorn and elder occur occasionally. There is a belt of sycamore along the western edge of compartment 71.

In Rireas, Scots pine is the major species and grows pure. There are also three areas of pure Corsican pine.

2. Structure. Single-storied high forest.

3. Height. The top height of the 100 largest trees per acre in compartments 70-72 is 45 feet. In Rireas they are smaller - 43 feet for the older trees and 35 feet for the younger ones.

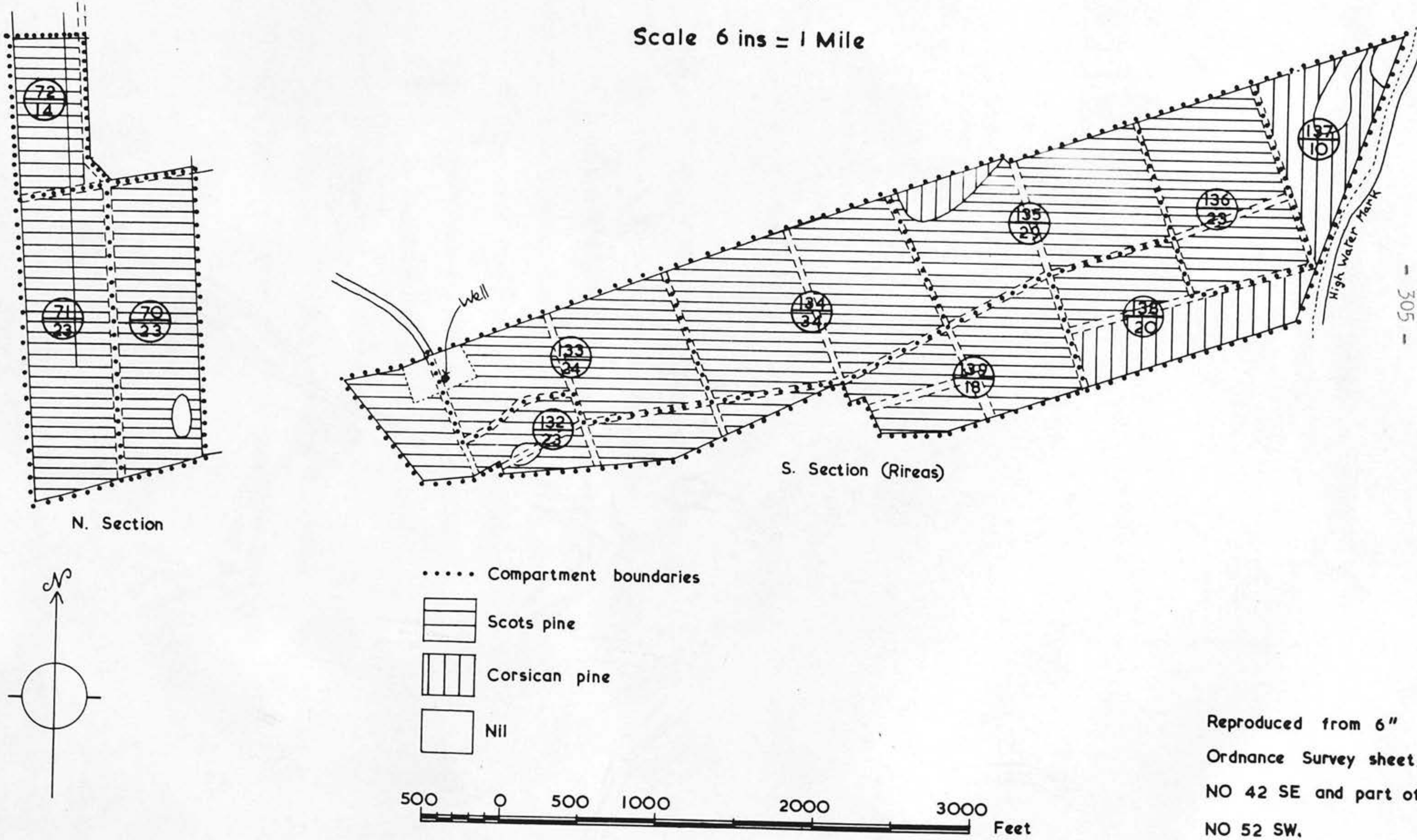
4. Canopy.

North Section		South Section (Rireas)	
Cpt.	Canopy %.	Cpt.	Canopy %
70	90. Towards centre of cpt. 65.	132	90
		133	95
		134	90
71	80 - 95	135	W. block 95
72	90		E. block 100
		136	100
		137	50 - 100
		138	Scots pine 95
			Corsican pine 95 - 100
		139	70

Tentsmuir Forest

Stand Map

Scale 6 ins = 1 Mile



Reproduced from 6"
Ordnance Survey sheet:
NO 42 SE and part of
NO 52 SW.

5. Origin, age and development stage. Origin of both sections of the working area is from planting.

Compartment	Species	Age	Development stage
N. Section			
70	Scots pine	38	Large pole to small timber
71	Scots pine	38	Large pole to small timber
72	Scots pine	32	Medium pole
S. Section (Rireas)			
132	Scots pine	35	Small to large pole
133	Scots pine	35	Small to large pole
134	Scots pine	35	Small to large pole
135 W.	Scots pine	35	Medium pole to small timber
block	Corsican pine	35	Medium timber
E. block	Scots pine	25	Small to large pole
136	Scots pine	25	Small to large pole
137	Corsican pine	25	Medium pole to small timber
138	Scots pine	25	Small to large pole
	Corsican pine	25	Medium pole to small timber
139	Scots pine	35	Small to large pole

6. Form and condition. The form of both the Scots and Corsican pine is good. There has been damage from the Pine Looper moth but this is confined to compartments 70-72. The Pine-shoot moth, however, has damaged many trees in both sections. The trees near the seafront in compartments 137 and 138 have scorched foliage and there is an area in compartment 137 where the trees are in check. The Scots pine in compartment 72 shows signs of ill health.

7. Natural regeneration. There is occasional regeneration of birch, sycamore and hawthorn in compartments 70-72.

8. Stocking and volume.

Compartment	Species	No./acre	Vol./acre H.ft.O.B.
N. Section			
70	Scots pine	600	1,880
71	Scots pine	600	1,860
72	Scots pine	600	1,600
S. Section (Rireas)			
132	Scots pine	850	1,700
133	Scots pine	850	1,700
134	Scots pine	850	1,700
135 W	Scots pine	850	1,700
E	Scots pine	1,200	950
136	Scots pine	1,200	950
137	Corsican pine	1,200	1,200
138 N	Scots pine	1,200	950
S	Corsican pine	1,200	1,200
139	Scots pine	850	1,700

9. Acreage.
(i) Total . . . . 241.0 acres
(ii) Present productive . . . 234.7 "
Scots pine . . . . . 210.6 "
Corsican pine . . . 24.1 "
(iii) Present unproductive . . 6.2 "
(iv) Potentially productive . 241.0

C. PAST AND PRESENT TREATMENT

1. Forestry. Rireas was planted in 1927 but a fire burnt compartments 138, 137, 136 and the western half of 135. These areas were replanted in 1937. The younger stands are now being thinned for the first time. The older compartments have had three thinnings and a fourth has been marked and is likely to take place this year. No brashing or pruning has been carried out.

Compartments 70 and 71 in the main forest block have had **four** thinnings to date while compartment 72, being 6 years younger, has had only **three** thinnings.

Grazing started two years ago.

2. Grazing. General. Grazing started in the autumn of 1960. The rent obtained in the first year was £40 for the 241 acres but because the tenant was expected to fence some of the area the rent has been reduced to £10 per grazing season. A lease is drawn up each year which states the duration of the grazing period, rent and other conditions of use.

(i) Season of use. Up to the present time the forest has been used for out-wintering from the end of September to the end of January. Should the tenant wish it this period would be extended by the Forestry Commission but as it is desirable for the cows to calve outside the forest the season of use will not extend beyong the middle of February.

(ii) Type of stock. Blue-grey cross Galloways are kept in Rireas and pure Galloways in the main forest block.

(iii) Stocking. 50 beasts in Rireas create a stocking rate of 1 cow to $3\frac{1}{2}$ acres. 40 beasts use the main forest block, giving a stocking rate of 1 cow to $1\frac{1}{2}$ acres.

(iv) Condition of vegetation. The vegetation is directly influenced by the amount of light penetrating the forest canopy. There is a good growth of grass along forest rides, extending approximately $\frac{1}{2}$ chain into the stand on both sides of the rides. Within the stand the vegetation lacks density, except in compartment 137 of Rireas, where the Corsican pine has not closed canopy and the sward is moderately dense.

The condition of the vegetation is good and from the grazing aspect has improved in both sections of the working area. This is most noticeable in compartment 70 of the main forest block, where before grazing started the vegetation was in small patches throughout the stand. Now there is an almost continuous covering of green grass with no matt of old grass leaves and stalks to present a fire hazard. The improvement is probably due to several causes: (a) the stock are removed at the end of January before growth commences and therefore the grass is not weakened by the removal of foliage before it has had a chance to replenish its food reserves; (b) the vegetation is allowed to seed; (c) the sward has a whole growing season during which it is untouched and has time to store up food reserves for the following year.

(v) Water. In Rireas water is obtained from a well at the western end of the plantation. In the main forest block stock can drink from an artificial drainage channel situated in compartments 71 and 72.

(vi) Damage to the stand. Along well-defined cattle tracks the roots of trees have been exposed and badly barked. In the area of checked Corsican pine in compartment 137 of Rireas (Plate 55) the leading shoots have not been damaged but occasional side shoots have been browsed. This damage is not serious.

D. POSSIBLE FUTURE TREATMENT

1. Controlling factors.

(i) Objects of management: "(1) to create a forest capable of producing a sustained yield;

(2) to achieve the highest production of timber of species suited to the locality, and

(3) to maintain, and if possible improve, the fertility and texture of the soil." These objects are to be realised by the following principles of management:

"(1) the abnormal age-class distribution will be converted to an approximately regular age distribution by systematic felling at a pre-rotation age;

(2) the felled areas will be replanted with Corsican and Scots pine of good provenance to form the timber crop, and

(3) a small proportion of broadleaved species and such conifers as produce a less acid leaf litter will be introduced into the economic crop to enrich the humus."

(ii) Requirements for out-wintering. Protection from wind is of prime importance. The wind data on page 295 shows that in the months from September to January the wind is in excess of 12 m.p.h. on an average of 10 days in each month.

(iii) Site. Both sections of the forest are adjacent to the tenant farmer's property and are easily accessible to man, livestock and machinery, which makes them useful for out-wintering.

There is also a limited amount of forage within the forest which is valued by the farmer as it provides a clean bite for the cattle in the months before calving. The forester benefits from this as it reduces the fire hazard.

Hay is fed within the forest after the animals have been there approximately five weeks.

2. Treatment.

This site is suitable for evaluating the effect of grazing on forest stands. The altitude, topography, climate, soil, vegetation and stands are more or less constant over the whole forest which would allow direct comparisons to be made between grazed and ungrazed areas. It is considered that this could best be achieved by discarding the concept of a sylvo-pastoral objective for this site, and instead of allowing the forestry enterprise to continue normally, with the objects and principles of management remaining as they are, and grazing taking place as and where forest operations allow it.

It is recommended that work be initiated on the comparison of the present grazed areas with similar ungrazed parts of the forest to observe the effect of grazing on the forest as it changes with age under the routine operations. The points that should receive attention are:

(1) The effect of grazing on the quality, quantity and distribution of vegetation and the influence of the age of the stands (i.e. crown density, canopy per cent, thinning operations, etc.) on these factors. Casual observations have indicated that in the northern section of the forest grazing has caused a spread of grasses through the stands and that the density of vegetation has slightly increased. The effect of grazing on the fire hazard will need consideration in this connection. At present grazing considerably reduces the danger of fire but whether this will continue to be so, as the stand opens out and the vegetation increases,

is unknown.

(2) The effect of grazing on the species of vegetation. It is possible that the dominance of the species may change, due to different palatabilities and susceptibilities to treading.

(3) The effect of grazing on soil properties, particularly the pH, humus content, porosity and crumb structure.

(4) The effect of grazing on the stand. It has been mentioned that Fomes is prevalent in the forest. The damaging of surface roots by animal hooves would provide an entry for this fungus and it is possible that there may be an increase in mortality due to butt rot.

(5) The effect on livestock of out-wintering in woodlands. This could be determined by out-wintering a number of the tenant farmer's cattle outside the forest and comparing their condition, weight, amount of food required, etc., with those in the woodland.

In addition, it would be of considerable value to obtain woodland microclimatic data in both grazed and ungrazed areas, for there is a lack of such information in this country.

CHAPTER 12

SUMMARY AND CONCLUSIONS

1. The objects of this work have been to review as wide a field as possible relating to the practice of out-wintering farm stock in woodlands in order (1) to establish the actual and/or potential value of woodlands for out-wintering livestock, (2) to explore methods of regeneration for these woodlands, and (3) to discover the problems involved in the management of such woodlands.

2. The field work was carried out in two parts, the first being preparatory to the second. The first consisted of touring much of Scotland to inspect areas of woodland being used for out-wintering purposes and obtaining information on this practice. From these sites, six were selected for detailed study (comprising the second part of the field work) for the purpose of investigating the possibility of integrating out-wintering with forest management and suggesting methods of achieving this.

3. It is apparent from touring much of Scotland that productive, well-managed hardwood and conifer stands, as well as the semi-productive and unproductive woodlands, are being used for out-wintering farm stock. Of the latter type, birch and oak are common and it has been found that many of the birch areas are in urgent need of regeneration if a tree cover is to be maintained.

4. It is clear that the out-wintering of cattle is often an economic necessity, as the provision of buildings for in-wintering and the purchase and storage of extra food supplies are expenses beyond the means of most farmers. It

was found that shelter for out-wintering cattle was valuable and in many cases essential. Shelter for sheep is desirable but not indispensible.

5. The shelter requirements for out-wintering farm stock have not been clearly defined by the agriculturist, although there is general agreement that protection from cold winds and a combination of wind and precipitation is desirable, and there is some difference of opinion as to whether over-head shelter or side shelter is preferable. It is apparent, however, that local climatic conditions will partly influence this choice for it has been found that in the generally colder and more rigorous climate of the east of Scotland, shelter is of prime importance for out-wintering purposes, whereas in the somewhat milder climate of the west the provision of adequate grazing during the winter months is more desirable. All gradations between these two extremes have been encountered.

It is also evident that the intensity of land use influences this choice. In regions of high fertility, where land use is intensive, it is uncommon for woodlands to be accessible to livestock, and only side shelter is available in the lee of fenced plantations and shelterbelts.

6. Woodlands provide valuable alternative wintering grounds as the arable land can be "rested" during the winter and this prevents the soil from being poached. Yet there is a tendency for farmers to regard such woodlands, particularly unmanaged ones, as "waste" ground, with the result that these areas are commonly overstocked with animals and

the trees suffer accordingly.

7. Although existing tree shelter is considered valuable for out-wintering farm stock, few farmers are prepared to carry out regeneration. In most cases this is due to a lack of capital for long-term investment. Any surplus revenue is devoted to improvements which will yield a relatively quick monetary return, such as reseeding hill land to increase the head of livestock.

8. Woodlands which are easily accessible to man, livestock and machinery are likely to be of most use for out-wintering, but the loss of dung for arable land and increased fencing costs are disadvantages tending to dissuade farmers from using them.

9. Field studies have shown that the type of damage to be expected from allowing livestock into woodlands is browsing; barking of tree trunks by cattle horns, gnawing and rubbing; barking of surface tree roots by hooves; treading in of ditches. On the other hand livestock can be beneficial in reducing a fire hazard by breaking up and distributing litter and slash and preventing an accumulation of inflammable vegetation.

Damage to soils was not investigated in this study but there is ample evidence, from a review of the literature, that it occurs. This important subject will need considerable attention before recommending or deprecating out-wintering in woodlands. In the meantime, it would be wise to restrict, as much as possible, the access of livestock to woodlands and discontinue the present, and generally unnecessary, practice of yearlong use.

10. Observations on the effect of a tree cover on the quantity of vegetation produced under it suggest that, during the growing season, the canopies of many hardwoods have as significant an effect as those of conifers in suppressing ground vegetation. Notable exceptions are larch and birch. There are also indications that coppice supports a greater quantity of ground vegetation than high forest. These observations are broadly similar to results obtained by workers in other countries but it would be useful to confirm the present findings by quantitative experiments.

11. Exploratory experiments on the quality of grasses in woodlands, compared with similar vegetation on open ground, suggest that there is little significant difference in chemical composition between the two. This is in agreement with François (1953) and Ovington (1956) but contrary to results obtained by Guise (1939) and Hawley and Stickel (1959). Further information on this subject is desirable with particular reference to the nutrient content of the grasses during winter and their palatabilities.

12. Regeneration will need protection from livestock, entailing a reduction in the area available for shelter and grazing. In small woodlands this reduction will be serious and a silvicultural system is indicated which involves small regeneration areas. Larger woodlands can be more easily sub-divided for regeneration and rotational use, for which the silvicultural system will probably be selected according to the intensity of future management.

BIBLIOGRAPHY

Ager, T. (1956). Le pâturage sylvo-pastoral dans l'économie alpestre de la Bavière. Bulletin de la Fédération française d'Économie alpestre, Grenoble, No. 7, 1956-7.

Agricultural Statistics (Scotland), 1958. (1960). H.M.S.O., Edinburgh.

Anderson, M.L. (Unpublished). History of Scottish Forestry.

Anderson, M.L. (Unpublished). Management plan for the period 1953/54 to 1963/64 for the Woodlands on the Boghall, Bush and Dryden Estates in the County of Midlothian.

Anderson, M.L. and Fairbairn, W.A. (1955). Division of Scotland into climatic sub-regions as an aid to silviculture. Bull. For. Dep. Univ. Edinb. No. 1.

Armstrong, D.G. et al. (1959). The effect of environmental conditions on food utilisation by sheep. Anim. Prod. 1(1), (1-12).

Armstrong, S.F. (1937). British Grasses and their Employment in Agriculture. Camb. Univ. Press, 3rd ed.

Baskett, T.S. et al. (1958). Ten-year timber cutting cycle provides a continuing supply of forage. Sta. Note Cent. St. For. Exp. Sta. No.125

Blaxter, K.L. (1958). Nutrition and climatic stress in farm animals. Proc. Nutr. Soc. 17, (191-6).

Blaxter, K.L. (1961). The nutritional physiology of live-stock under natural conditions. J. R. Soc. Arts 109, Sept., No.5062 (764-81).

Caborn, J.M. (Unpublished). Wind measurements at Boghall Farm.

Caborn, J.M. (1957). Shelterbelts and Microclimate. Bull. For. Comm. No.29, H.M.S.O., Edinburgh.

Chandler, R.F.(jr.) (1940). The influence of grazing upon certain soil and climatic conditions in farm woodlands. J. Amer. Soc. Agron. 32(3), (216-30).

Charlesworth, J.K. (1957). The Quaternary Era. Edward Arnold, London.

Churchill, W.S. (1957). A History of the English Speaking Peoples, Vol. I. Cassell, London.

Cowan, J. (1857). Report on providing shelter for hill stock upon exposed land. Trans. Highl. agric. Soc. Scot. 1857-9, n.s., (173-89).

Darling, F.F. (1955). West Highland Survey. Oxford Univ. Press.

Davies, W. (1952). The Grass Crop. E. & F.N.Spon, London.

von Dietze, C. (1955). Agriculture and Forestry; competition or coexistence? International J. Agrarian Affairs 2(2), (113-19).

Edlin, H.L. (1956). Trees, Woods and Man. Collins, London.

Edlin, H.L. and Nimmo, M. (1956). Tree Injuries. Thames and Hudson, London.

Edmond, D.B. (1958). Animal treading and pastures. Agric. Rev., London, July.

*Ehrenreich, J.H. (1960). Usable forage under pine stands. Sta. Note Cent. St. For. Exp. Sta. No.42

Ehrenreich, J.H. and Crosby, J.S. (1960). Herbage production is related to hardwood crown cover. J. For. 58(7), (564-5).

Ellison, W. (1953). Marginal Land in Britain. Geoffrey Bles, London.

Encyclopaedia Britannica (1959). Encyclopaedia Britannica Ltd., London, Chicago, Toronto.

Eskeland, A. (1955). Agriculture aand Forestry; competition or coexistence? International J. Agrarian Affairs 2(2), (159-68).

Fagan, T.W. and Watkins, H.T. (1932). The chemical composition of the miscellaneous herbs of pastures. Welsh J. Agric. 8, (144-51).

Fenton, E.W. (1953). The influence of man and animals on the vegetation of certain hill grazings in mid-east Scotland. Edinb. Sch. Agric. Tech. Bull. No.7.

Findlay, J.D. and Beakley, W.B. (1955). In Progress in Physiology of Farm Animals, Vol. 2. Butterworths Scientific Publications, London.

François, T. (1953). Grazing and Forest Economy. F.A.O. For. & For. Prod. Stud. No.4, Rome.

Franklin, T.B. (1952). A History of Scottish Farming. Nelson and Sons Ltd., Edinburgh.

Franklin, T.B. (1953). British Grasslands. Faber and Faber, London.

Fürst, H. (1893). The Protection of Woodlands. David Douglas, Edinburgh.

Geiger, R. (1957). The Climate near the Ground. Harvard Univ. Press.

Giöbel, G. and Waesterberg, T. (1960). Hagmarksproblemet. K.Skogs-o. LantbrAkad. Tidskr., Stockh., 99(3/4), (212-33).

Guise, C.H. (1939). The Management of Farm Woodlands. McGraw-Hill Book Co. Inc.

Haarløv, N. (1960). Microarthropods from Danish Soils. Oikos 3.

Hawley, R.C. and Stickel, P.W. (1959). Forest Protection. 2nd ed. John Wiley & Sons, New York.

Hughes, R. and Nicholson, I.A. (1960). Maintenance of reclaimed land. Scot. Agric. 40, (152-6).

*Kaminaga, T. et al. (1956). Sheep grazing on larch-planted land. Ann. Rep. For. Exp. Sta., Hokkaido.

Kidd, D.D. (1957). Grazing intensity - Its effect on botanical composition. Agric. Rev., London, 2(8), (25-30).

Kittredge, J. (1948). Forest Influences. McGraw-Hill Book Co. Inc.

Lachaussée, E. (1954). L'équilibre agro-sylvo-pastoral dans le Jura. Rev. For. franç. 6(12), (769-90).

Lamb, H.H. (1959). Our changing climate, past and present. Weather, London, 14(10), (299-318).

Landale, S.E.A. (1961). Shelter for profit in the hills of south-east Scotland. Scot. Agric. 40(4), (197-204).

Leaf, A.L. (1958). Effect of grazing on fertility of farm woodlot soils in Southern Wisconsin. J. For. 56(2), (138-9).

Lee, D.H.K. (1949). In Proc. Specialist Conference in Agric. "Plant and animal nutrition in relation to soil and climatic factors."

Leloup, M. (1953). Elements of Forest Fire Control. F.A.O. For. & For. Prod. Stud. No.5.

Le problème de l'équilibre agro-sylvo-pastoral. Rev. for. franç. 6(12), (717-825).

Lull, H.W. (1959). Soil compaction on forest and range lands. U.S. For. Serv. Misc. Publ. No.768.

Madgwick, H.A.I. and Ovington, J.D. (1959). The chemical composition of precipitation in adjacent forest and open plots. Forestry 32(1), (14-22).

Maki, T.E. and Mann, W.F.(jr.) (1951). Some effects of sheep grazing on Longleaf pine. J. For. 49(4), (278-81).

Manley, G. (1952). Climate and the British Scene. Collins, London.

Michael, D.T. (1960). Aspects of shelter in relation to the grazing animal. Scot. For. 14(3), (130-5).

Michie, C.Y. (1885). The Larch. Blackwood & Sons, Edinburgh.

Munro, J. (1961). Shelter for livestock. Hill Farming Research Organisation, 2nd report, Edinburgh.

*Mustafaev, H.M. (1957). Vlizanie usilennoj past'by skota na počvu v lesnyh polosah. Lesn. Hoz. 10(4), (80-1).

Mutch, W.E.S. (Personal communication).

Mutch, W.E.S. (1958). High elevation forest margins. Scot. For. 12(3), (147-54).

McCavish, W.L. (1952). A grazing experiment in Redesdale Forest. J. For. Comm., London, 23, 1952-4, (57-8).

MacKinnon, J. (1892). Culture in Early Scotland. Williams & Norgate, London.

MacLeod, A. (1959). The development and improvement of natural shelter. Scot. Agric. 39, 1959-60, (86-7).

Nägeli, W. (1961). Der Einfluss von zerstreut wachsenden Bäumen und Baumgruppen auf die Windverhältnisse von Weideland. Proc. Congr. int. Union For. Res. Organ., Vienna, 1961.

Nehring, K. and Schütte, J. (1950). Über die Zusammensetzung und den Futterwert von Laub und Reisig. I. Mitteilung. Über die Änderungen in der Zusammensetzung von Laub und Reisig verschiedener Baumarten in Abhängigkeit von der Vegetationszeit. Arch. Tierernähr. 1(3), (151-76).

Nehring, K. and Schramm, W. (1951a). Über die Zusammensetzung und den Futterwert von Laub und Reisig. II Mitteilung. Über die Verdaulichkeit von Laub und Sommerreisig. Arch. Tierernähr. 1(5), (264-89).

Nehring, K. and Schramm, W. (1951 b). Über die Zusammensetzung und den Futterwert von Laub und Reisig. III Mitteilung. Über den Futterwert von Fallaub und Winterreisig. Arch. Tierernähr. 1(6), (342-60).

Nichols, J.E. (1955). Shelterbelts in relation to hill farming. Scot. For. 9(2), (58-64).

Nisbet, J. (1893). British Forest Trees. MacMillan & Co., London.

Ovington, J.D. (1954). A comparison of rainfall in different woodlands. Forestry. 27(1), (41-53).

Ovington, J.D. (1956 a). The composition of tree leaves. Forestry 29(1), (22-8).

Ovington, J.D. (1956 b). Studies of the development of woodland conditions under different trees. V. The mineral composition of the ground flora. J. Ecol. 44(2), (597-604).

Ovington, J.D. (1959). The calcium and magnesium contents of tree species grown in close stands. New Phytol. 58, (164-75).

Pearsall, W.H. (1950). Mountains and Moorlands. Collins, London.

Perrin, H. (1952). Sylviculture. II. Le Traitement des Forêts Théorie et Pratique des Techniques sylvicoles, Nancy.

Piggot, S. (1954). The Neolithic Cultures of the British Isles. Camb. Univ. Press.

Poncet, A. (1956). Mélèzes et pâturages. Bulletin de la Fédération française d'Économie alpestre, Grenoble, No.7, 1956-7, (206-20).

Read, R.A. (1957). Effect of livestock concentration on surface-soil porosity within shelterbelts. J. For. 55(7), (529-30).

Rieben, E. (1957). La Forêt et L'Économie Pastorale dans Le Jura. Thesis presented to L'École polytechnique fédérale, Zurich.

Ritchie, J. (1920). The Influence of Man on Animal Life in Scotland. Camb. Univ. Press.

Robertson, -. (1958). Notes on the common grazings in the Highlands of Scotland. Cyclostyled paper, 1958.

Royal Commission on Common Land, 1955-58. Cmnd. 462. H.M.S.O., London.

Russell, E.W. (1961). Soil Conditions and Plant Growth. Longmans.

Sampson, A.W. (1923). Range and Pasture Management. John Wiley & Sons. New York.

Sampson, A.W. (1952). Range Management; principles and practices. John Wiley & Sons, New York.

Selly, C. Article in the "Observer", London, 12/2/61.

Semple, A.T. (1951). Improving the World's Grasslands. F.A.O. agric. Stud. No.16.

Skinnemoen, K. (1957). An Outline of Norwegian Forestry. norske Skogselsk, Oslo.

Smith, G.A. (1926). The attack on the Forest Service grazing policy. J. For. 24(2), (136-40).

Smith, L.F. et al. (1958). Cattle grazing in Longleaf pine forest of south Mississippi. Occ. Pap. Sth. For. Exp. Sta. No.126.

Society of American Foresters (1926). Majority Report of the Committee on Grazing to the Executive Committee, Society of American Foresters. J. For. 24(4), (378-411).

Stamp, L.D. (1955). Man and the Land. Collins, London.

Stapledon, R.G. (1936). The improvement of hill land. Scot. J. Agric. 19(1), (14-24).

Stapledon, R.G. and Hanley, J.A. (1927). Grassland - Its Management and Improvement. Oxford Univ. Press.

Steinbrenner, E.C. (1951). Effect of grazing on floristic composition and soil properties of farm woodlands in Southern Wisconsin. J. For. 49(12), (906-10).

Stephens, H. (1891). The Book of the Farm, Vol.1. (Revised J. MacDonald). 4th ed. Blackwood & Sons, Edinburgh.

Steven, H.M. and Carlisle, A. (1959). The Native Pinewoods of Scotland. Oliver and Boyd, Edinburgh.

Stickel, P.W. and Hawley, R.C. (1924). The grazing of cattle and horses in pine plantations. J. For. 22(8), (846-60).

Stoddart, L.A. and Smith, A.D. (1943). Range Management. McGraw-Hill Book Co. Inc.

*Stoeckler, J.H. (1959). Trampling by livestock drastically reduces infiltration rate of soil in Oak and Pine woods in south-western Wisconsin. Tech. Note Lake St. For. Exp. Sta. No.556.

Swedborg, E. (1955). Agriculture and Forestry; competition or coexistence?. International J. Agrarian Affairs 2(2), (187-203).

Symon, J.A. (1959). Scottish Farming - Past and Present. Oliver and Boyd, Edinburgh.

Tansley, A.G. (1949). The British Islands and their Vegetation. Camb. Univ. Press.

Toumey, J.W. and Korstain, C.F. (1947). Foundations of Silviculture. Chapman and Hall, London. 2nd ed.

Tribe, D.E. (1950). The behaviour of the grazing animal; a critical review of present knowledge. J. Brit. Grassl. Soc. 5(3), (209-24).

Troup, R.S. (1928). Silvicultural Systems. Oxford Univ. Press, 2nd ed.

Trow-Smith, R. (1957). A History of British Livestock Husbandry to 1700. Routledge & Kegan Paul, London.

Urquhart, B. (1953). Small woods. Scot. Agric. 33(1), (200-3).

Wannop, A.R. (1947). The out-wintering of beef cows. Scot. J. Agric. 26(4), (203-7).

Wannop, A.R. (1958). A review of hill farm problems. Advanc. Sci. 15(59), (189-94).

Whyte, R.O. (1957). The Grassland and Fodder Resources of India. Indian Coun. of Agric. Res., New Delhi.

Wilson, A.S.B. (1936). The improvement of rough hill pasture by cattle-grazing. Scot. J. Agric. 19(4), (364-6).

Wooten, H.H. (1955). Agriculture and Forestry; competition or coexistence? International J. Agrarian Affairs 2(2), (169-85).

* Original not seen.